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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

HIGH ORDER PARAMETRIC X-RADIATION FROM SILICON AND LITHIUM FLUORIDE CRYSTAL MONOCHROMATORS

by

Joseph R. Thien

December, 1995

Thesis Advisor: Xavier K. Maruyama

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13. ABSTRACT

This thesis examines parametric x-radiation (PXR) generated by Silicon and Lithium Fluoride monochromators, including the first observation of PXR from Lithium Fluoride. Parametric x-radiation may be described as the Bragg scattering of virtual photons associated with relativistic electrons as they pass through single crystal monochromators. As the photons interact with the crystal lattice they produce x-rays which meet the Bragg condition $n\lambda = 2d\sin\theta_B$, where θ_B is the angle between the electron beam and the crystal plane. PXR data were collected from Silicon and Lithium Fluoride crystals using a SiLi detector. The locations of the energy peaks are compared to the locations predicted by theory and the intensity ratios between the peaks are also compared to the theoretical ratios. The PXR energy observed was as predicted by theory for Silicon and Lithium Fluoride monochromators. The observed peak intensity ratios for Silicon were not in agreement with intensity ratios predicted by theory. Intensity ratios observed from Lithium Fluoride were in agreement with the predicted value.

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HIGH ORDER PARAMETRIC X-RADIATION FROM SILICON AND LITHIUM FLUORIDE CRYSTAL MONOCHROMATORS

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

This thesis examines parametric x-radiation (PXR) generated by Silicon and Lithium Fluoride monochromators, including the first observation of PXR from Lithium Fluoride. Parametric x-radiation may be described as the Bragg scattering of virtual photons associated with relativistic electrons as they pass through single crystal monochromators. As the photons interact with the crystal lattice they produce x-rays which meet the Bragg condition $n\lambda = 2d\sin\theta_B$, where θ_B is the angle between the electron beam and the crystal plane. PXR data were collected from Silicon and Lithium Fluoride crystals using a SiLi detector. The locations of the energy peaks are compared to the locations predicted by theory and the intensity ratios between the peaks are also compared to the theoretical ratios. The PXR energy observed was as predicted by theory for Silicon and Lithium Fluoride monochromators. The observed peak intensity ratios for Silicon were not in agreement with intensity ratios predicted by theory. Intensity ratios observed from Lithium Fluoride were in agreement with the predicted value.

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ACKNOWLEDGMENT

I. INTRODUCTION

The need for sources of intense monochromatic x-rays has led to the study of the interaction of relativistic charged particles in various materials. Different mechanisms of generating x-rays are compared by Baryshevsky and Feranchuk [Ref. 1]. Parametric x-radiation (PXR) may be an important source of intense, monochromatic x-rays. PXR is the scattering of virtual photons associated with a relativistic charged particle, by the atomic planes of a crystal lattice at the Bragg or Laue condition. Ter-Mikaelian first developed the theory of PXR for thin crystals [Ref. 2] which was expanded by Feranchuck and Ivashin to include thick crystals [Ref. 3]. The first experimental verification of the theory of PXR was conducted in the Soviet Union by Baryshevsky, et. al., using the 900 MeV electron beam at the Tomsk synchrotron [Ref. 4].

The first experimental observation of PXR outside the Soviet Union was at the Naval Postgraduate School (NPS) using a 100 MeV electron linear accelerator. The first experiments were done using thin silicon crystals and carbon graphite mosaic crystals. [Ref. 5]

This thesis explores the energy and intensity ratio relationship between the PXR peaks generated by four different thicknesses of silicon crystals and compares these results to the peak relationships predicted by theory. The generation of PXR from a lithium fluoride crystal is observed for the first time in these experiments. These measurements are also compared to the values predicted by theory.

II. THEORETICAL BACKGROUND

A. PARAMETRIC X-RADIATION (PXR)

Parametric x-rays (PXR) are generated when a relativistic charged particle interacts with a crystal's periodic dielectric constant. Ter-Mikaelian described the radiation produced by a thin periodic crystal. [Ref. 2] PXR occurs in crystals thicker than the x-ray extinction length,

$$\kappa L \mid n\text{-}1 \mid \geq 1 \tag{1}$$

where L is the crystal thickness, κ is the emitted photon wave number and n is the crystal index of refraction [Ref. 6]. When an ultrarelativistic electron ($E \gg mc^2$) enters a crystal its electromagnetic field can be represented as a superposition of virtual photons. The electromagnetic interaction of ultrarelativistic electrons within a crystal is equivalent to the interaction of a photon beam within the crystal. PXR can be considered the result of virtual photon diffraction in the crystal [Ref. 6]. To analyze the interaction of virtual photons in a crystal we can use the results from the theory of X-ray diffraction and resonant γ-radiation. It is convenient to use natural units with $\hbar = c = 1$. In the ultrarelativistic electron case the virtual photon momentum can be written as,

$$\kappa = \omega \frac{v}{v^2} \approx \omega v \tag{2}$$

where $v =$ the velocity and $\omega =$ the virtual photon frequency. The virtual photons whose momenta satisfy the Bragg condition

$$(\kappa + \tau)^2 \approx \kappa^2 \tag{3}$$

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are diffracted by the crystal, where τ is the reciprocal lattice vector. This leads to PXR in the $(\kappa + \tau)$ direction as shown in Figure 1. The photons are emitted from the crystal at an angle not dependant on the energy but at an angle defined by the particle's angle relative to the crystallographic plane. [Ref. 6].

reciprocal lattice vector
τ

crystal planes

θ_B θ_B

κ_B κ

parametric x-rays
(real photons)

charged particle beam
(virtual photons)
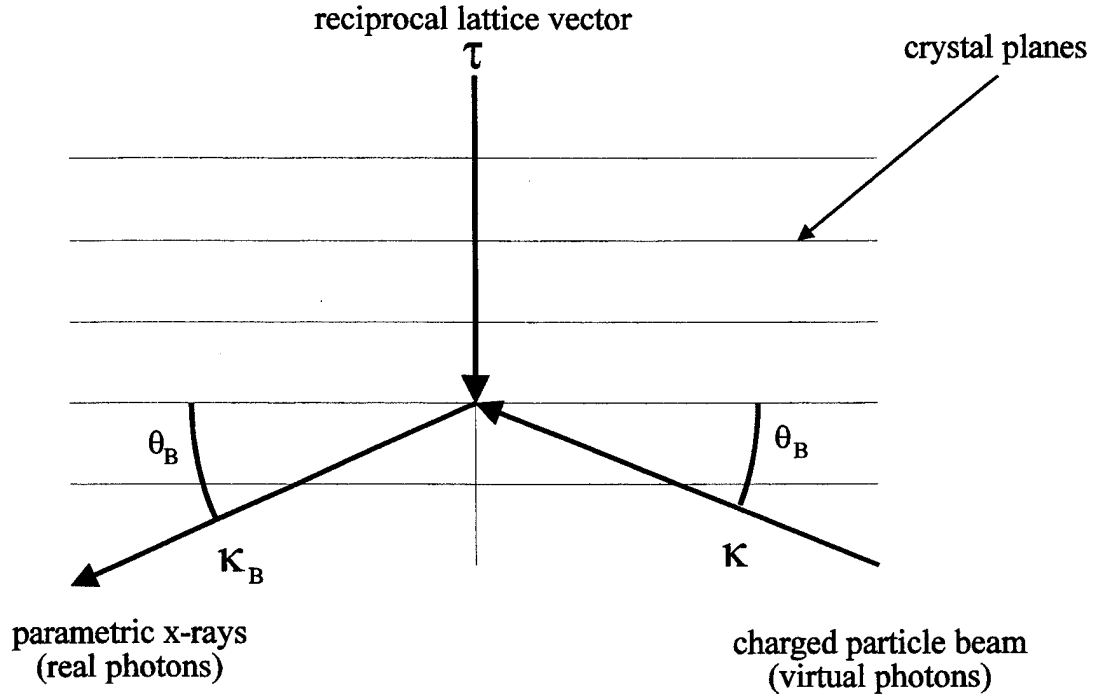
Figure 1. Parametric X-rays produced by diffraction of virtual photons by the planes of a crystal lattice.

1. PXR Energy

The emitted photon energy E, is calculated using Bragg's Law as follows;

$$n\lambda = 2d\sin\theta_B \ , \qquad\qquad E = \frac{hc}{\lambda} \qquad\qquad (4)$$

$$E = \frac{nhc}{2d\sin\theta_B} , \qquad\qquad (5)$$

using conventional units, where n = the order of the reflection, λ = the wavelength of the

emitted photon, d=the distance between crystal planes, θ_B=the angle between the electron beam and the crystal plane, h=planck's constant and c=the speed of light.

2. PXR Intensity

This qualitative description of PXR demonstrates that PXR gives the same reflections as those formed when an X-ray beam is diffracted by the crystal [Ref. 7]. In the following discussion we sketch the treatment of Reference 7 using natural units with $\hbar=c=1$. PXR as well as X-ray diffraction can be treated two ways: 1) as dynamic theory and 2) as kinematic theory. The first case is realized in ideal crystals while kinematic theory is applicable to real crystals which consist of thin mosaic blocks turned relative to each other at the angle $\delta > m/E$. Kinematic diffraction is more convenient for experimental observation of PXR and can be most easily analyzed since the angular and spectral distributions of PXR are simplified and have a universal form for different crystals. If one takes into account the refraction of photons and the multiple scattering of electrons in the crystal then the spectral and angular distributions of emitted photons is given by [Refs. 7,8]:

$$\frac{\partial^2 N}{\partial n_\perp \partial \omega} = \frac{e^2}{2\pi} \omega L_a |g_\tau|^2 \frac{|\kappa_B \times (\omega v + \tau)|^2}{\left[(\kappa_\perp - \tau_\perp)^2 + \frac{\omega^2}{v^2}(1-v^2)\right]^2} \left[1 - e^{-\frac{L}{L_a}}\right]\delta(q) \tag{6}$$

$$q = \frac{\omega}{v} - \sqrt{\omega^2 - \kappa_\perp^2} + \tau_z - \frac{\omega}{2}(\mathrm{Re}g_0 - \theta_s^2) \tag{7}$$

$$\theta_s = \frac{E_s}{E}\sqrt{\frac{L}{L_R}} \tag{8}$$

from the general formula (18) in Reference 6. Here g_τ, g_0 are the Fourier components of the crystal dielectric constant; θ_s is the angle of multiple scattering; $E_s \simeq 21$ MeV from

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Reference 7, and L_R is the radiation length. Equations (6-8) are written in the coordinate system with the z-axis directed along the particle velocity v, $\kappa_\perp = \omega n_\perp$; and $L_a = (\omega \mathrm{Im} g_0)^{-1}$ is the absorption length of the crystal for X-rays of angular frequency ω, L is the thickness of the crystal. [Ref. 7] Analysis of Equations (6-8) shows that PXR consists of a series of peaks which coincide with the directions of diffractions of real photons with frequency ω_B which penetrate into the crystal at angle θ_B relative to the crystallographic planes defined by the reciprocal lattice vector τ. The distribution of PXR depends upon the crystal structure and on the angle between the particle and the crystallographic planes.

The angular distribution of PXR can be determined by integrating Equation (6) over ω. [Ref. 7] The result is

$$\frac{\partial^2 N}{\partial \theta_x \partial \theta_y} = \sum_{n=0}^{\infty} \frac{e^2}{4\pi} \omega_B^{(n)} L_a \left[1 - e^{-\frac{L}{L_a}}\right] \frac{\left|g_\tau(\omega_B^{(n)})\right|^2}{\sin^2 \theta_B} \cdot \frac{\left[\theta_x^2 \cos^2 2\theta_B + \theta_y^2\right]}{\left[\theta_x^2 + \theta_y^2 + \theta_{ph}^2\right]^2}; \tag{9}$$

$$\theta_{x,y} = \frac{(\kappa - \kappa_B)_{x,y}}{\omega_B}; \qquad \omega_B^{(n)} = \frac{\pi n}{d \sin \theta_B}; \tag{10}$$

$$\theta_{ph}^2 = \frac{m^2}{E^2} + \theta_s^2 - \mathrm{Re} g_0 \tag{11}$$

where d is the distance between the crystallographic planes corresponding to the vector τ, and θ_{ph} is the angular spread of the reflection. Equations (9-11) can be put into a dimensionless form by means of the normalized amplitude $J \equiv N/N_0$ and angles $x,y = \theta_{x,y}/\theta_{ph}$:

$$\frac{\partial^2 N}{\partial x \partial y} = N_0 J(x,y); \qquad J(x,y) = \frac{x^2 \cos^2 2\theta_B + y^2}{(x^2 + y^2 + 1)^2}; \tag{12}$$

$$N_0 = \sum_{n=1}^{\infty} \frac{e^2}{4\pi} \omega_B^{(n)} L_a \left[1 - e^{-\frac{L}{L_a}} \right] \frac{\left| g_\tau(\omega_B^{(n)}) \right|^2}{\sin^2\theta_B}. \tag{13}$$

The frequency distribution of PXR can be obtained by integrating Equation (6) over $\mathbf{n}_\perp$ [Ref. 7],

$$\frac{\partial N}{\partial u} = N_1 J_1(u); \qquad J_1(u) = \frac{1 + u^2(1 + \cos^2 2\theta_B)}{\left[1 + u^2 \right]^{\frac{3}{2}}} \tag{14}$$

where

$$N_1 = \frac{\pi}{2} N_0; \qquad u = \frac{\sin\theta_B}{\cos\theta_B} \frac{(\omega - \omega_B)}{\omega_B \theta_{ph}}. \tag{15}$$

The total number of photons recorded by a detector of angular size θ_D about θ_B is defined by the following expression [Ref. 7],

$$\begin{aligned}
N_D &= \pi N_0 (1 + \cos^2 2\theta_B) \int_0^{\rho_D} \frac{\rho^3 d\rho}{\left(\rho^2 + 1\right)^2} \\
&= N_1 (1 + \cos^2 2\theta_B) \left[\ln \frac{\theta_D^2 + \theta_{ph}^2}{\theta_{ph}^2} - \frac{\theta_D^2}{\theta_D^2 + \theta_{ph}^2} \right]
\end{aligned} \tag{16}$$

where

$$\rho_D = \frac{\theta_D}{\theta_{ph}}. \tag{17}$$

References 6 and 7 were used extensively to develop the preceding discussion.

B.   PEAK RATIOS

The absolute amount of PXR generated by a crystal can be calculated by using Equation (16). This calculation is complex and does not provide results that can easily be compared to experimental data. The PXR theory can be compared to the experimental results by calculating ratios between the peaks in the PXR spectrum. This is done by

comparing the $n = 2,3,...$ peaks (from the summation in Equation (13)) to the $n = 1$ peak. Substituting Equations (13) and (15) into Equation (16), dividing peak n by peak 1 and canceling factors yields

$$\frac{N_{d_n}}{N_{d_1}} \propto \frac{N_{0_n}}{N_{0_1}} = \frac{\omega_b^{(n)}}{\omega_b^{(1)}} \frac{L_{a_n}}{L_{a_1}} \frac{\left[1-e^{\frac{-L}{L_{a_n}}}\right]}{\left[1-e^{\frac{-L}{L_{a_1}}}\right]} \frac{|\ g_\tau(\omega_b^{(n)})|^2}{|\ g_\tau(\omega_b^{(1)})|^2} \tag{18}$$

where L is the crystal thickness and L_a is the x-ray absorption length,

$$|g_\tau| = \left| \frac{4r_e\lambda^2}{\pi V} f_1\left(\frac{\sin\theta_B}{\lambda}\right) \right|, \tag{19}$$

where f_1 is the x-ray scattering factor, V is the crystal unit cell volume and r_e is the classical electron radius [Refs. 6,7,9], and with

$$\lambda = \frac{2d\sin\theta_B}{n}, \qquad \omega_b^{(n)} = \frac{\pi n}{d\sin\theta_B}, \tag{20}$$

substituted into Equation (18) yields,

$$\frac{N_{0_n}}{N_{0_1}} = \frac{1}{n^3} \frac{L_{a_n}}{L_{a_1}} \frac{\left[1-e^{\frac{-L}{L_{a_n}}}\right]}{\left[1-e^{\frac{-L}{L_{a_1}}}\right]}. \tag{21}$$

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III. PXR EXPERIMENT

Several PXR measurements were made using a 1.75 mm thick Silicon monochromator mounted on an Aluminum holder and a 1 mm thick Lithium Fluoride monochromator mounted on a similar Aluminum holder. The data from the Silicon crystal was compared to previous data taken from 20 μm, 44 μm, and 320 μm Silicon crystals [Ref. 5]. This data was reanalyzed using the procedures described later.

A. ACCELERATOR OPERATION

The Naval Postgraduate School (NPS) Electron Linear Accelerator (LINAC), shown in Figure 2, was used to conduct these experiments. The LINAC has a rated beam energy of 100 MeV but the actual beam energy varied with each experiment. The beam energy was 96 MeV for these experiments except for one Lithium Fluoride run which was conducted at 62 MeV.

The LINAC is pulsed at 60 Hz with a macro structure length of 1 μsec. The SiLi detector used has a nominal time resolution of 12 μsec determined by the pre-amplifier. To prevent double counting, (two photons entering the detector at nearly the same time being counted as one photon of higher energy) the LINAC was run using dark current only for data runs to limit the number of photons detected over the energy range of the detector to one every three to five machine pulses. Dark current is achieved by turning the gun grid voltage off and accelerating only stray electrons. This yields a current estimated to be less than 2 x 10^{-13} Amperes. It is important to eliminate double counting

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during PXR experiments since two photons from the $n=1$ reflection added together have the same energy as one photon from the $n=2$ reflection. Double counting will cause the ratios between the observed peaks to be wrong. Maintaining a constant dark current was difficult and required constant operator attention [Ref. 10].
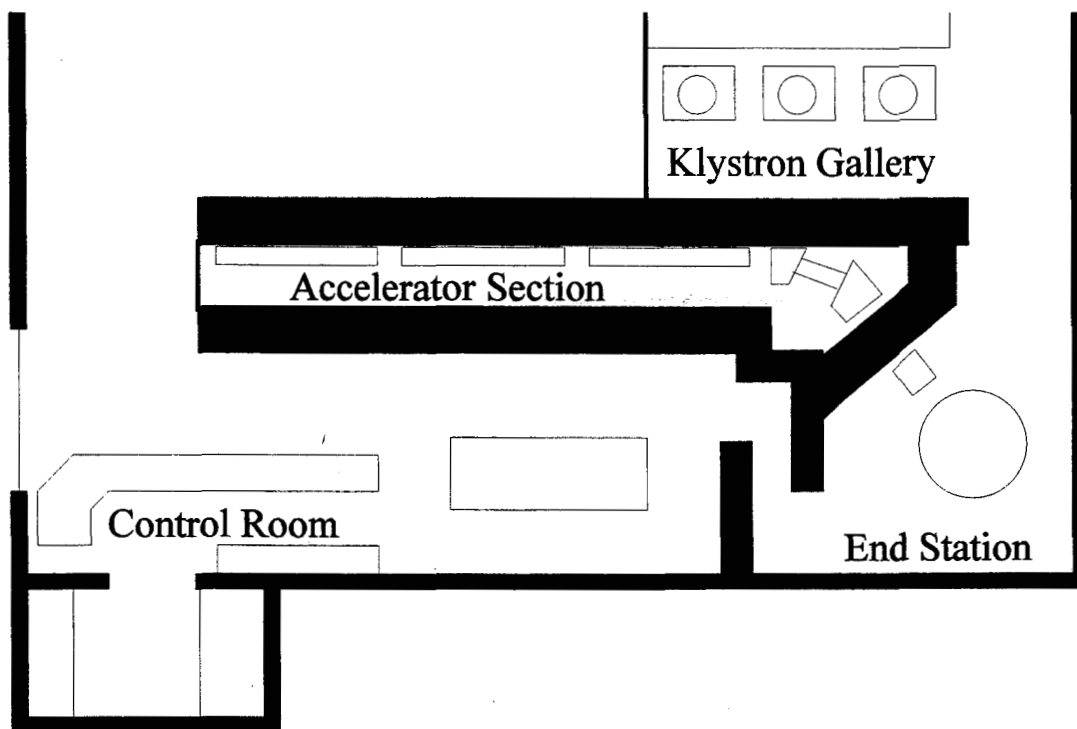
Figure 2. Naval Postgraduate School 100 MeV Linear Accelerator.

B.   BEAM ALIGNMENT

Beam alignment during PXR experiments is critical since the energy of the PXR observed depends upon the angle that the beam enters the crystal. To align the beam the LINAC was operated in the normal mode and the beam was steered to pass through a pinhole in a phosphorescent screen located at the center of the experimental chamber mounted on the ladder assembly and to strike the middle of a phosphorescent screen

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located at the beam exit port as shown in Figure 3. These screens were observed by television cameras monitored in the control room.
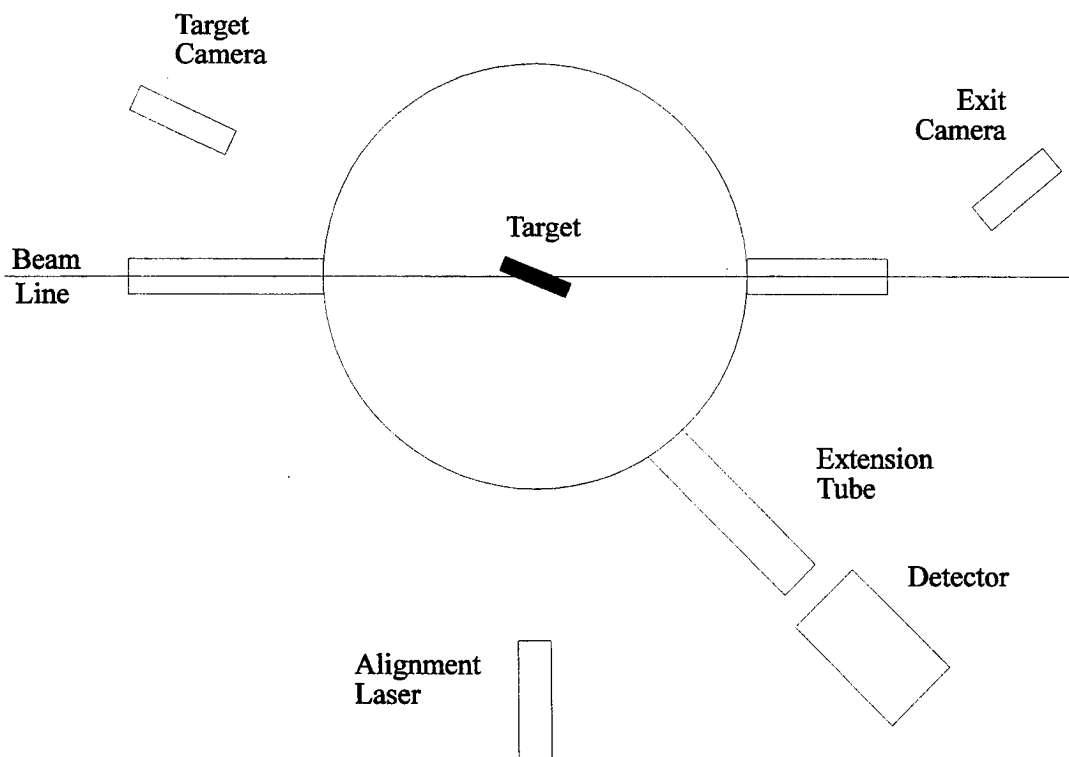
Figure 3. PXR experiment end station setup.

The target monochromators were mounted on the upper portion of the ladder assembly shown in Figure 4. The ladder assembly can rotate through 360 degrees controlled by a computer controlled motor. The upper portion of the ladder assembly can be tilted forward and backwards to ensure that the crystal is perpendicular to the beam. This tilt is also controlled by a computer controlled motor. In order to ensure that the crystal is perpendicular to the beam an alignment laser is bounced off of the crystal (or for crystals that do not reflect, a front silvered mirror was mounted adjacent

to the crystal) and the position of the reflection is observed by a television camera monitored in the control room. The motors controlling ladder movement are adjusted until proper alignment is achieved. This can be a tricky process since there is some backlash in the motor couplings and gears moving the ladder.

The ladder assembly consists of two sections. The fixed lower section which held the phosphorescent alignment screen and the tri-foil calibration stack. There is also an open position and room for other calibration foils. The upper tilting section of the ladder holds an aluminum plate which has cutouts for mounting up to three different target monochromators and an alignment mirror.
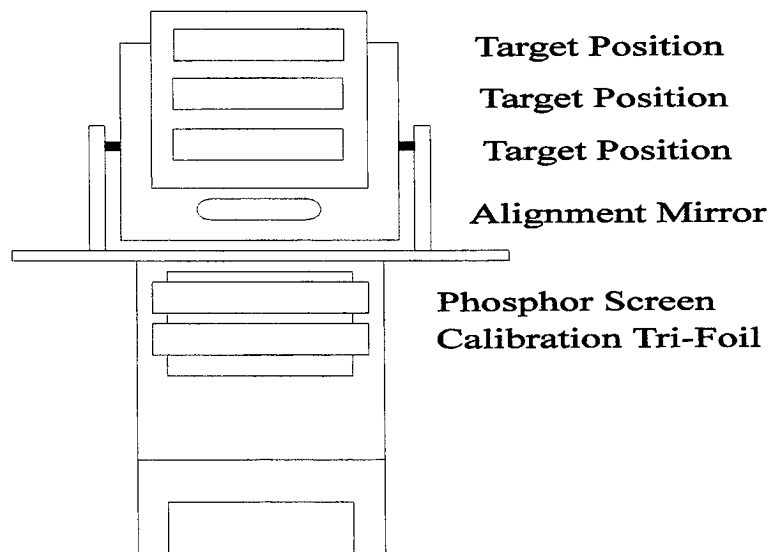
Figure 4. Target and calibration foil ladder assembly.

C. DETECTOR AND ELECTRONICS

The detector used for these PXR experiments was a Canberra Model SL200250 series 7300 Lithium drifted Silicon (SiLi) detector. The detector had an active area of 200 mm^2 and was 5 mm thick. The detector was mounted 5 mm behind a 0.05 mm Beryllium window and maintained under a vacuum and cooled in a cryostat to liquid nitrogen temperatures. [Ref. 11]

The detector was placed at the end of a 40.3 cm extension tube placed on the experimental chamber. The extension tube had a 0.025 mm kapton window. There was a 1 cm air gap between the extension tube window and the detector window. T h e detector high voltage power supply and ORTEC 571 preamplifier were located in the LINAC end station while the amplifier, counters and pulse height analyzer were located in the control room. The electronic signal connections are diagrammed in Figure 5. Due to the proximity of the end station to the klystron gallery shielding the detector and end station electronics was very important. Shielding included wrapping the electronics enclosure and detector with copper mesh screening that was then grounded. Proper grounding and trial and error shielding were important to reduce klystron noise.

The output of the preamplifier was then sent to the control room where it was amplified by a TENNELEC TC 244 amplifier then sent to a TENNELEC TC 304 linear gate. The gate was triggered by a Stanford Research System model DG 535 four channel digital delay/pulse generator. The output of the gate was sent to a digital counter, a two channel oscilloscope and a NUCLEUS Personal Computer Analyzer

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(PCA-II) card installed in an IBM compatible personal computer. The PCA-II software

was operated in the Pulse Height Analyzer (PHA) mode. [Ref. 12]
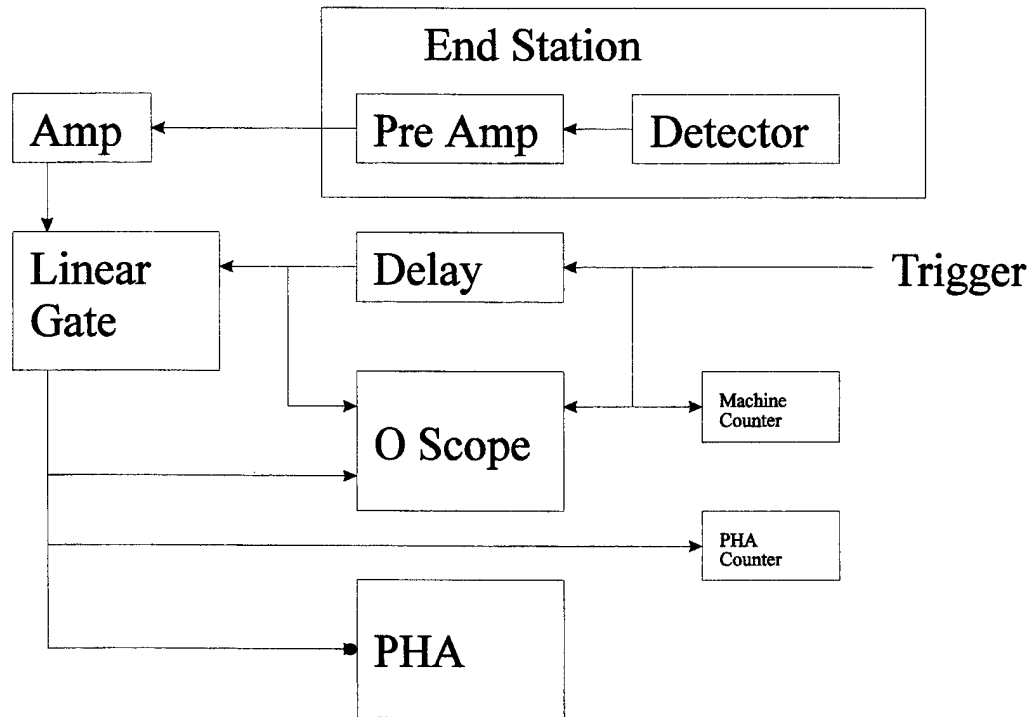
Figure 5. PXR Electronics Setup.

The pulse generator was triggered by the T_0, LINAC pulse start time signal. This

signal was also used to trigger the oscilloscope and was sent to a digital counter to count

machine pulses. The ratio between the machine pulse counter and the PHA counter was

observed by the operators and used to control the dark current. To prevent double

counting this ration was kept between 1:3 and 1:6.

The pulse generator delay time was adjusted so the start of the gate coincides with

the arrival of the beam pulse at the target. The signal to the PHA and the pulse

generator output were observed on the oscilloscope and the width of the gate and the

delay time were adjusted so the detector pulse would be recorded by the PHA but any stray pulses and klystron noise would not be recorded. The optimum delay time, determined by trial and error, was 25 μsec with a width of 46 μsec.

IV. DATA COLLECTION

A. ENERGY CALIBRATION

Prior to conducting any PXR experiment the detector and electronics setup required an energy calibration. The calibration was determined by observing the x-ray fluorescence lines from a sandwich of tin, titanium and yttrium foils, shown in Figure 6, inserted into the LINAC electron beam path [Refs. 10,13]. Data collection time for
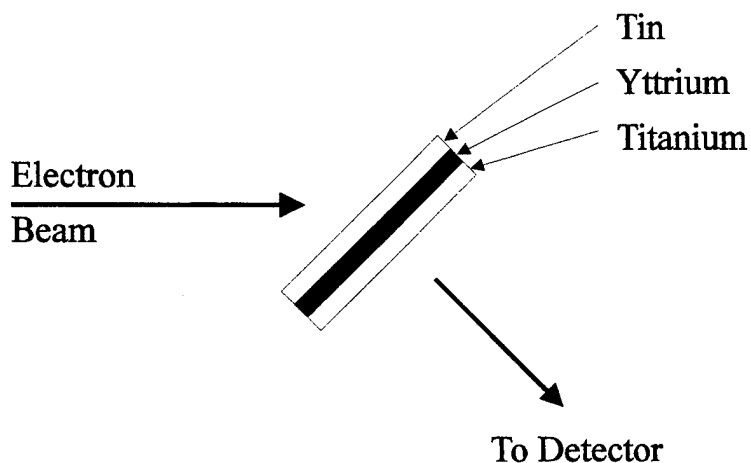
Figure 6. Tri-Foil used to determine energy calibration by observing x-ray fluorescence lines.

an energy calibration run varied, the calibration run data was collected until distinct x-ray fluorescence peaks were observed on the PHA. A typical calibration run output is shown in Figure 7. The calibration spectrum was then saved to disk for later analysis. A rough energy calibration was performed by estimating the peak channel numbers and performing a linear regression fit on a handheld calculator using x-ray fluorescence line data [Ref. 14]. This was done to ensure that the data being collected was at roughly the

predicted energy. During long data collection runs a second energy calibration run was conducted as a precaution after completion of data collection to take into account any drift in detector response during data collection. In all cases observed drift was negligible.
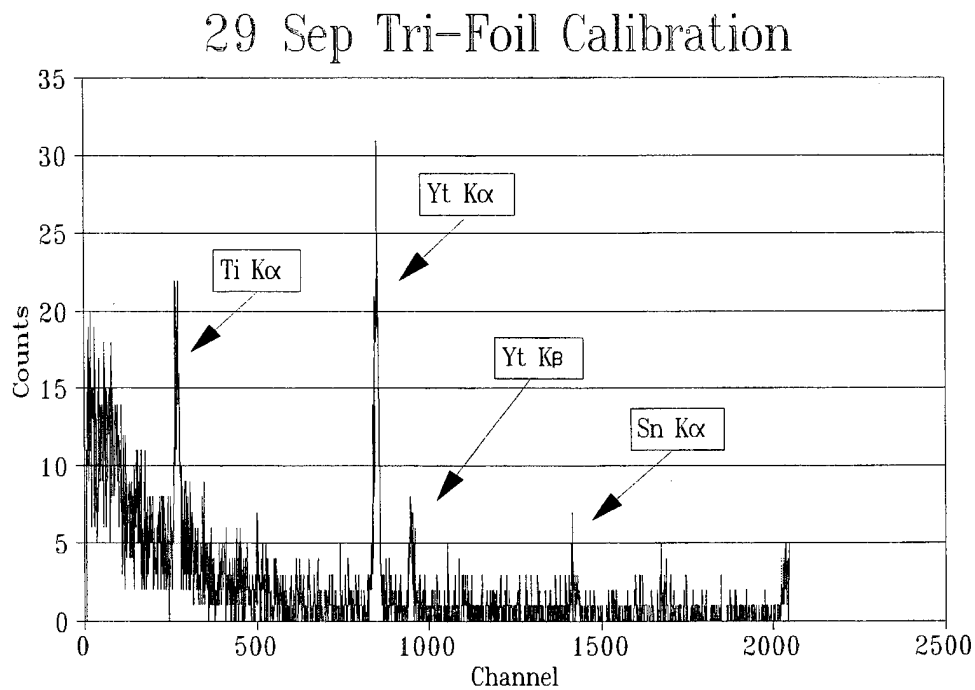
Figure 7. Typical x-ray fluorescence lines observed during an energy calibration run using the Titanium, Yttrium, and Tin tri-foil.

B. PXR DATA RUNS

After completion of the calibration run the ladder was moved down and rotated to place the crystal in the electron beam to collect PXR data. The counting rate during PXR data collection was reduced to the 1:3 to 1:6 ratio to prevent double counting. Data

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collection was done with the crystal plane at an angle of 22.5 degrees with respect to the electron beam. Data collection time varied from several to over twelve hours in order to observe as many peaks in the spectrum as possible. A typical PXR data collection run output is shown in Figure 8. Long data collection times enabled high order peaks to emerge above the background signal. The LiF runs were not as long as the Si runs since the object of the LiF runs was to take some exploratory data on PXR generated by the crystal since PXR from this target had never been observed. During the 29 September run a thin tin foil was placed behind the 1.75 mm silicon crystal and its 2 mm thick aluminum holder in an attempt to observe the tin x-ray fluorescence line during the data collection run to provide an energy reference as done during previous carbon mosaic crystal experiments [Ref. 5]. The tin x-ray fluorescence peak was not observed due to attenuation of the x-rays by the aluminum holder and the silicon crystal. A comparison of calculated x-ray attenuation factors of the silicon crystal in the aluminum holder, as in this experiment, and the 1.3 mm thick carbon mosaic crystal used in Reference 5, is shown in Figure 9. During all runs data was saved to disk every hour to aid in analysis and if necessary to subtract out times when the data may not have been ideal due to double counting or klystron noise.

A summary of PXR data collection runs is shown in Table 1. The data collection run on 22 October 1992 was cut short when a high voltage power supply failed. The data collection runs in December were done using dark current only without the main beam for initial set up and focusing since the electron gun had failed. This meant that the beam focusing had to be estimated which was done by observing the PXR spectrum

at various angles and choosing the angle where the count rate was the highest. The beam

angle error for these runs is estimated at ± 1 degree.
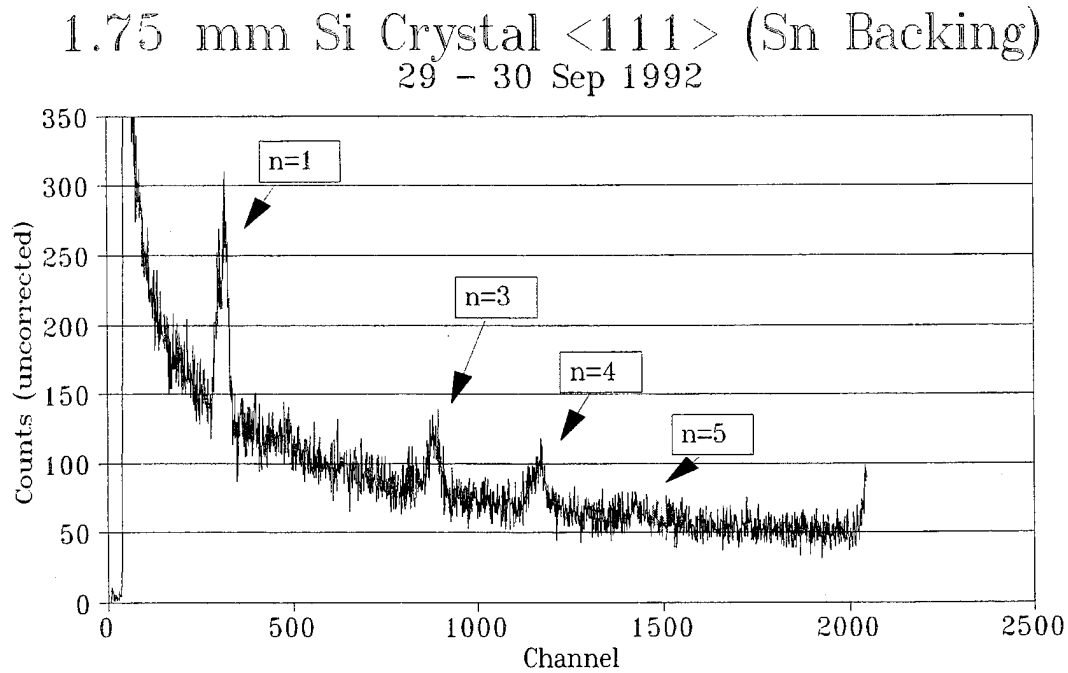
Figure 8. Typical PXR raw data spectrum of a 1.75 mm Silicon Crystal showing four peaks, $E_B = 100$ MeV, $\theta_B = 22.5°$. This run included a tin backing foil, however the tin line was not observed.

Crystal	Linac Energy	Date	Run Time
Si (111)	96 MeV	25 Sep 92	5½ Hours
Si (111)	96 MeV	29 Sep 92	12 Hours
Si (111)	91 MeV	2 Dec 92	3 Hours
LiF (220)	95 MeV	22 Oct 92	38 Min
LiF (220)	92 MeV	1 Dec 92	2¼ Hours
LiF (220)	62 MeV	3 Dec 92	2¾ Hours

Table 1. Summary of PXR Data Collection Runs.

X-Ray Attenuation
of Si in Al holder and C mosaic crystal
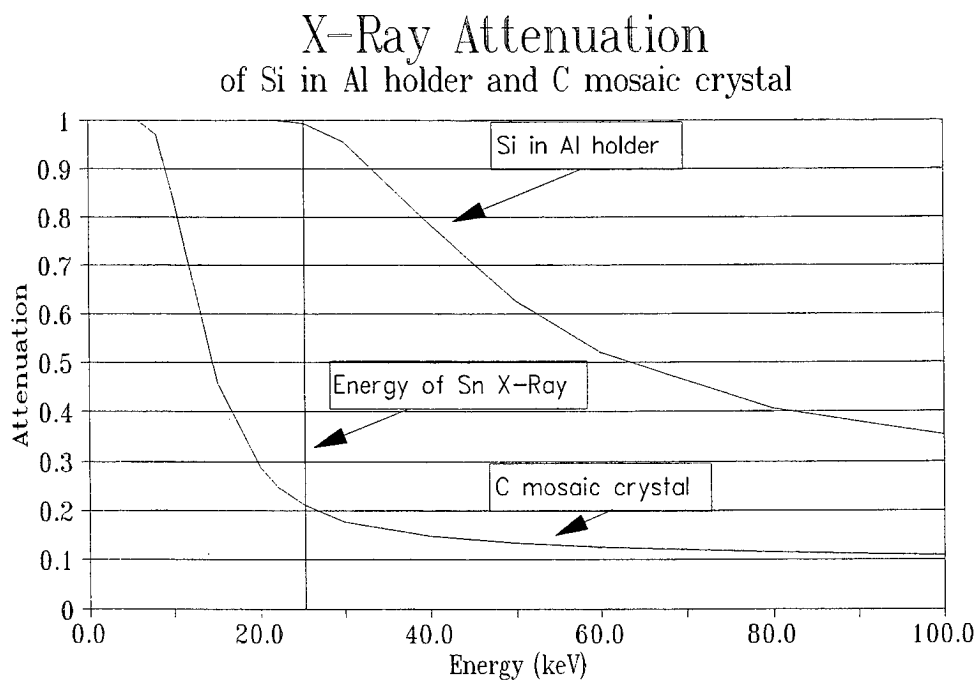
Figure 9. Comparison of x-ray attenuation factors for the Silicon Crystal in an Aluminum holder and a Carbon mosaic crystal.

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V. DATA ANALYSIS

A.   ENERGY CALIBRATION

The first step of data analysis was to use the energy calibration data and convert

channel number to energy. The raw energy calibration spectrum (shown in Figure 7)

was analyzed to find the center channel for each observed peak. This was done using

Peakfit, a program from Jandel Scientific [Ref. 15]. A typical Peakfit energy calibration

run output is shown in Figure 10.
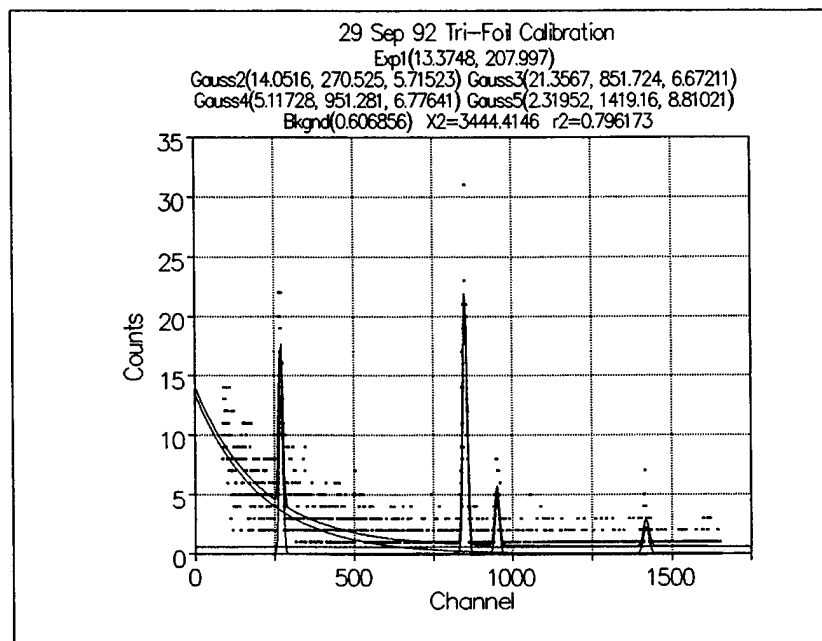
Figure 10. A Peakfit graphic output showing data, parameters of curves fit and graphic
output of curves and background.

Peakfit uses the Marquardt-Levenberg algorithm [Ref. 15] to find the minimum

value of the sum of the squared deviations between the data and the projected curve

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functions. The observed peaks were best fit using Gaussian functions while the background was a combination of an exponential and a linear function. Peakfit also provides a detailed numerical output. An edited version of this output is shown below. Sections of the output of particular interest are highlighted as shown. The Curve-Fit Std Error and r^2 give a measurement of the exactness of the fit of the data compared to other fit attempts. The Standard Error is

$$\text{Std } E = \left[\frac{\chi^2}{v} \right]^{1/2}, \tag{22}$$

where v = the number of degrees of freedom and χ^2 = the sum of the square of the residuals,

$$\chi^2 = \sum_{i=1}^{n} (y_i - Y_i)^2, \tag{23}$$

where y_i = y value of the curvefit at i^{th} data point, and Y_i = y value of ith data point. The coefficient of determination, r^2 is

$$r^2 = 1.0 - \frac{\sum_{i=1}^{n} (y_i - Y_i)}{\sum_{i=1}^{n} (y_i - \bar{y})}. \tag{24}$$

The Curve-Fit Coefficients section lists the final values of the coefficients used to determine all of the curves in the data set. The Measured Values section gives data for all of the curves in the set. The peak center (PkCtr) and the Area are the data values which are used in later analysis. The Peak# section gives detailed information about each

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peak including the standard error and confidence limit range for each parameter. The

last section consists of an analysis of variance for the curve-fit. [Ref. 15]

```
                      PeakFit Numerical Summary

Description:   29 Sep 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 1567
X Variable: Channel
Y Variable: Counts
File Source: CAL929X3.PRN


Curve-Fit Std Error= 1.4897447     r2= 0.796173001

Background Coefficients [y=a+bx+cx^2+dx^3]
Background         a          b          c          d
      Order=0    0.6068557


Curve-Fit Coefficients
Peak#   Type       Ampl       Ctr        Wid1       Wid2
   1  Exp        13.374803  207.99687
   2  Gaussian   14.051629  270.52525  5.7152349
   3  Gaussian   21.356656  851.7238   6.6721124
   4  Gaussian   5.1172806  951.28139  6.7764128
   5  Gaussian   2.3195225  1419.1646  8.8102087


Measured Values
Peak#   Type       PkAmpl     PkCtr      Wid@HM     Area       %Area
   1  Exp         0          0          0          0          0
   2  Gaussian    14.051629  270.52525  13.458337  201.30322  28.89673
   3  Gaussian    21.356656  851.7238   15.711563  357.18045  51.272637
   4  Gaussian    5.1172806  951.28139  15.957158  86.921956  12.477497
   5  Gaussian    2.3195225  1419.1646  20.746413  51.224134  7.353136
          Total                                    696.62975  100


Peak# 2  Gaussian
   PkAmpl         PkCtr         Wid@HM        Area
   14.05162926   270.5252467   13.45833709   201.3032188
   XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
   263.7960806   277.2544177   6.729166082   6.729171013
   Parm  Value         Std Error     t-value        95% Confidence Limits
   Ampl  14.05162926   0.576342916   24.38067489   12.92367189   15.17958663
    Ctr  270.5252467   0.269251155   1004.731983   269.9982968   271.0521965
   Wid1  5.715234918   0.273520137   20.89511577   5.179930249   6.250539587


Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 1.489744704     r2= 0.7961730012
Source   Sum of Squares    DF      Mean Square          F
Regr     13454.301         14      961.02153            433.021
Error    3444.4146         1552    2.2193393
Total    16898.716         1566
```

The peak centers, as determined by Peakfit, are matched up with the x-ray

fluorescence line energy from Reference 14 and a linear regression fit is performed using

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the spreadsheet Quattro Pro [Ref. 16]. Typical linear regression calculations used to determine energy are shown in Table 2.

Element	X-Ray Line	Channel	Energy (keV)
Ti	Kα	270.5	4.507
Yt	Kα	851.7	14.9
Yt	Kβ	951.3	16.9
Sn	Kα	1419.2	25.2

Constant		X Coefficient	
-0.48599		0.017963	

Table 2. Typical Linear Regression Calculations.

The linear regression fit is used to convert channel number to energy in a spreadsheet containing the PHA data using Equation 25,

$$E = a + bX, \tag{25}$$

where E is the Energy, a is the linear regression constant, b is the linear regression x coefficient and X is the Channel Number. Detailed energy calibration data, Peakfit curves, Peakfit data summaries and linear regression calculations are contained in Appendix A.

B.   PXR DATA ANALYSIS

Raw PXR data was collected by the PHA and stored on disk. Some of this data was collected using the 8K channel option and other data was collected using the 2K channel option [Ref. 12]. Two thousand channels were enough to provide the energy

resolution required and made the data files easier to manipulate using the spreadsheet. The energy resolution is 0.018 keV per channel in the typical 2K channel option and 0.0044 keV per channel for the 8K channel option. A Q-basic program was written to convert the 8K files to 2K. This program is listed in Appendix B.

The PHA data files were imported into the Quattro Pro spreadsheet and then the results of the energy calibration files were used to convert channel number to energy. This then yields the uncorrected PXR spectrum, a typical example is shown in Figure 11.
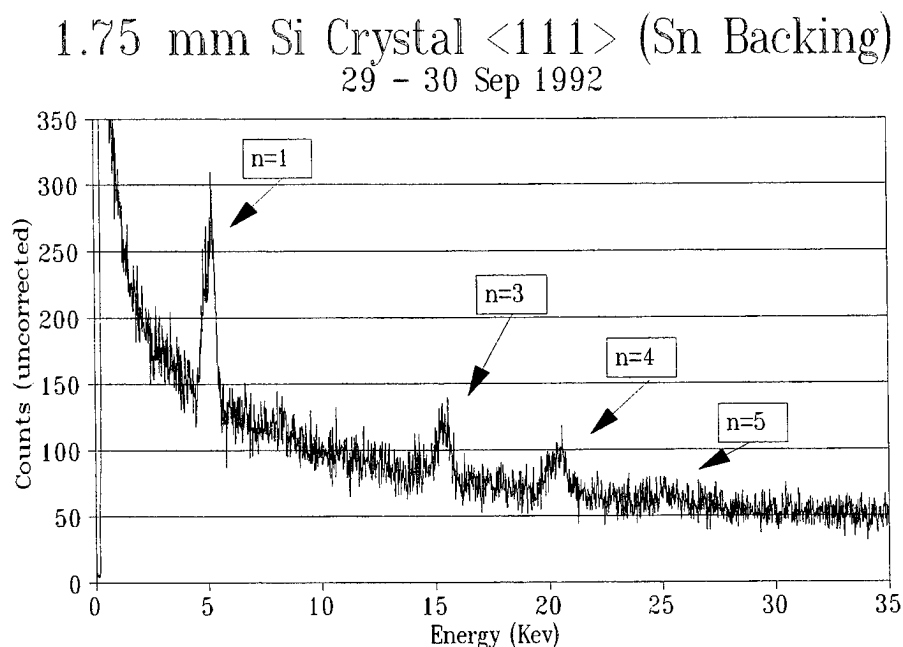
Figure 11. Typical uncorrected PXR spectrum after energy calibration of a 1.75 mm Silicon Crystal, $E_B=100$ MeV, $\theta_B=22.5°$. This is the raw data shown in Figure 8 calibrated using the energy calibration curve shown in Figure 10.

The PXR uncorrected line intensities are determined by using Peakfit to analyze the uncorrected data. Peakfit generates a graphical representation of the data, a typical

example is shown in Figure 12, as well as a detailed numerical output as previously

described.
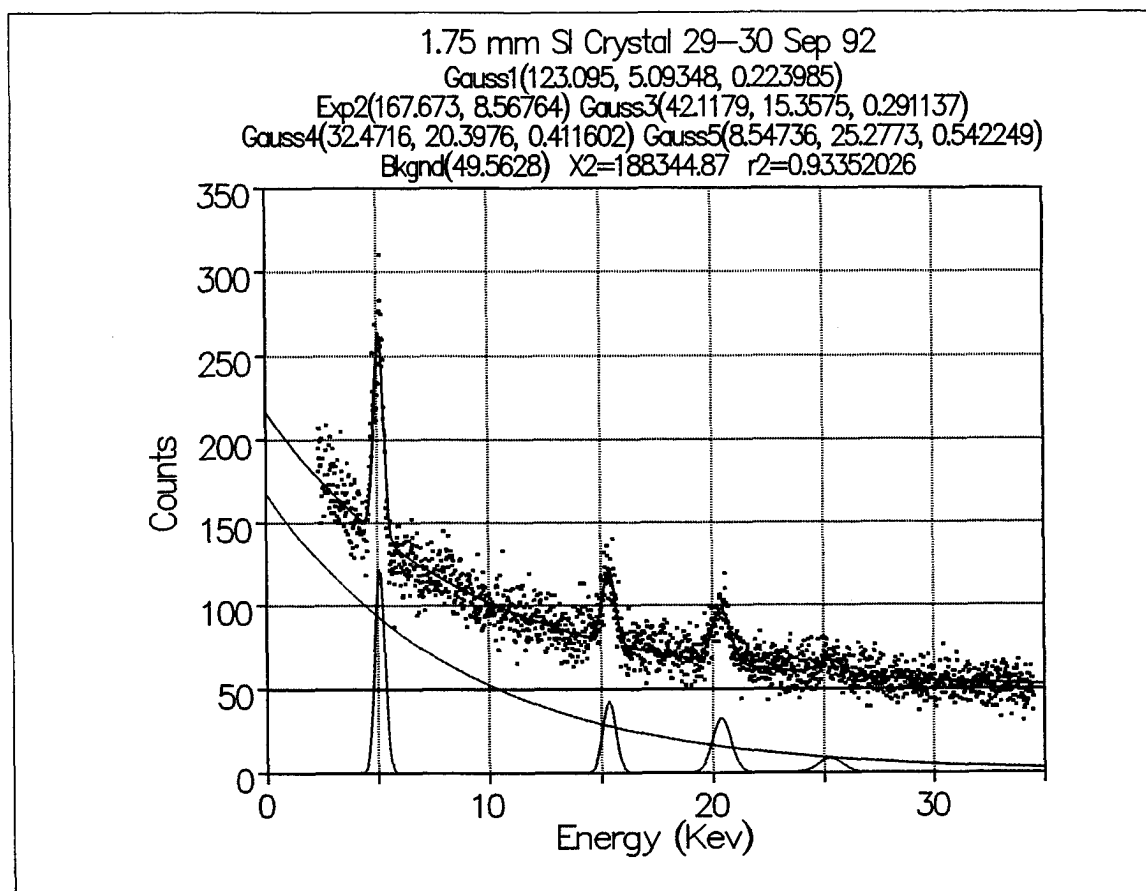
Figure 12. Typical uncorrected data Peakfit output. This is the peakfit data output for
the uncorrected 1.75 mm Silicon Crystal data shown in Figure 11.

Previously collected data from thin crystals [Ref. 5] were also analyzed using

these procedures and will be presented in Chapter VI. The uncorrected PXR spectrums

as well as the Peakfit numerical summaries are contained in Appendix C.

The spectrums collected must be corrected to show the true PXR spectrum since

the detected photons have had to travel through the kapton window at the end of the

experimental chamber extension tube, the air gap between the extension tube and the

detector and the beryllium window at the end of the detector. The detector response must also be considered since every photon that enters the detector does not result in a count out.

Attenuation of photons traveling through a material is described by

$$I = I_0 e^{-\mu \rho t} \tag{26}$$

where μ is the photon attenuation coefficient, ρ is the density of the material and t is the thickness of the material. The total attenuation correction is given by

$$I_0 = \frac{I_D}{e^{-\mu_{kap}\rho_{kap}t_{kap} - \mu_{air}\rho_{air}t_{air} - \mu_{Be}\rho_{Be}t_{Be}}}. \tag{27}$$

the attenuation coefficient μ depends upon the energy of the photon. A computer program, XCOM, was used to calculate attenuation coefficients [Ref. 17]. To correct the complete graph, XCOM's feature that allows calculation for an input energy grid was used to calculate a separate correction factor for each channel of data in the spectrum files. XCOM would only accept an energy grid of less than 500 points and since the data files are over 2000 channels various QBasic programs and command files were written to speed up this procedure, as detailed in Appendix D.

The attenuation coefficients were imported into the spreadsheet data files and then Equation 24 was applied to determine revised counts for each energy channel in the spectrum. Densities and thicknesses used are listed in Table 3.

The next correction to apply is the correction for detector efficiency. This was calculated using the attenuation coefficient for Si, as calculated by XCOM, and the

	Kapton	Air	Be
Composition (by mass)	$C_{22}O_5N_2H_{10}$	N_2 75.75% O_2 23.00% Ar 1.20% CO_2 0.05%	Be
ρ (gm/cm^3)	1.42	1.225x10^{-3}	1.85
t (cm)	0.0025	1	0.005

Table 3. PXR Attenuation Materials.

equation below,

$$DetectorEff = 1 - DetectorAtten. \qquad (28)$$

This data was then plotted, as shown in Figure 13 and compared to the published detector efficiency curves shown in Figure 14. [Refs. 11,18] The detector efficiency curves were compared but did not match. Figures 13 and 14 are superimposed in Figure 15 to demonstrate this comparison. It appeared that the calculated efficiency for a 3 mm detector matched the given efficiency for the 5 mm detector that was used so the 3 mm calculations were added to the spreadsheet data to determine the corrected counts in the spectrum files. A typical corrected PXR spectrum is shown in Figure 16.

Detector Efficiency
Calculated
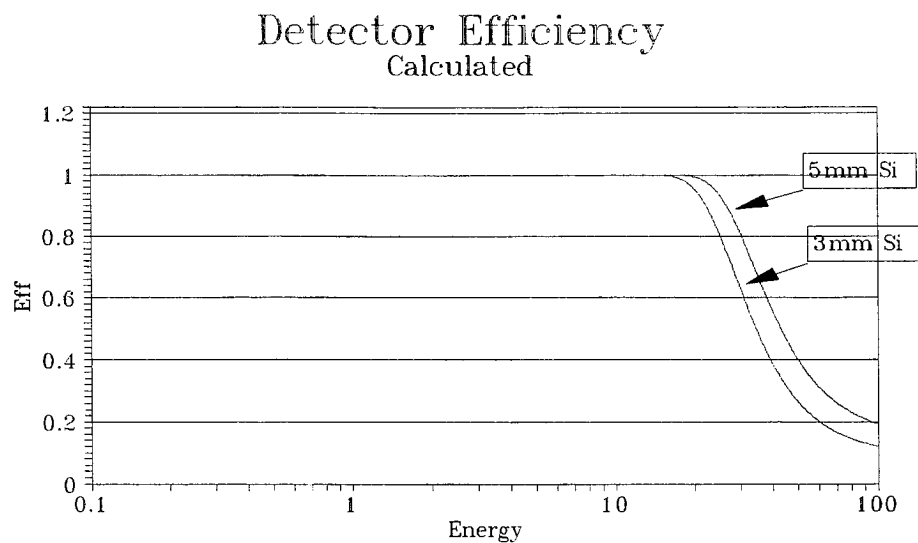
Figure 13. Silicon detector calculated efficiency curve using XCOM.
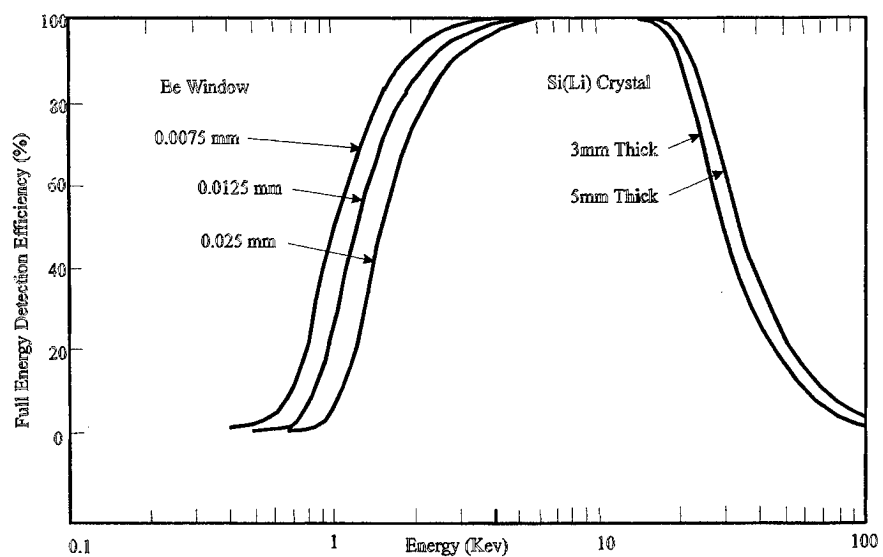
Figure 14. Silicon detector published efficiency curve. [From Refs. 11,18]

Detector Efficiency
Calculated
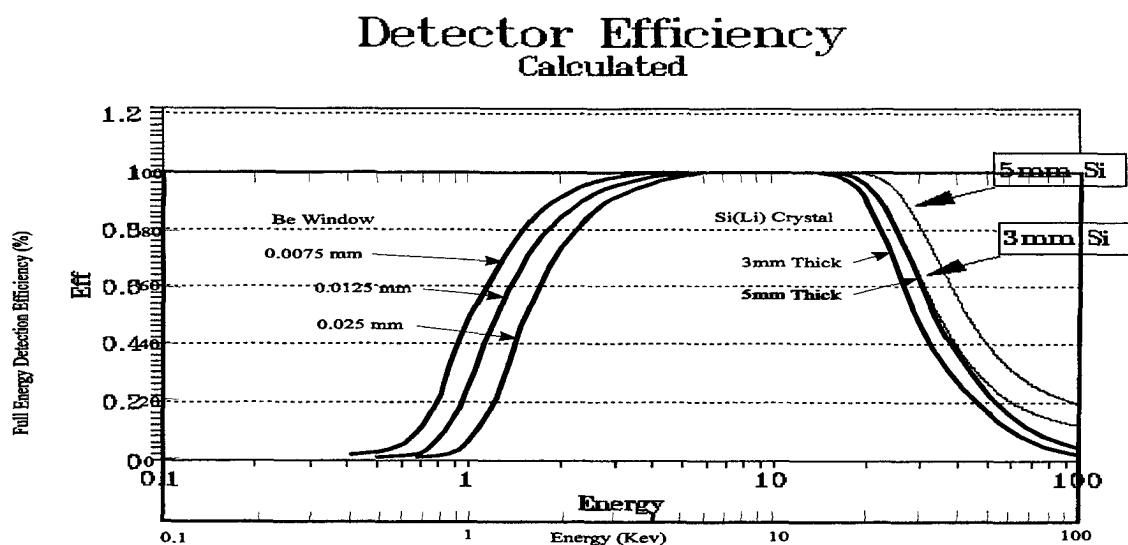
Figure 15. Superimposed calculated and published detector efficiency curves.

After correction for attenuation and detector efficiency the PXR spectrums were analyzed using Peakfit to determine the peak centers and intensities. The corrected spectrums and Peakfit numerical summaries are contained in Appendix E.

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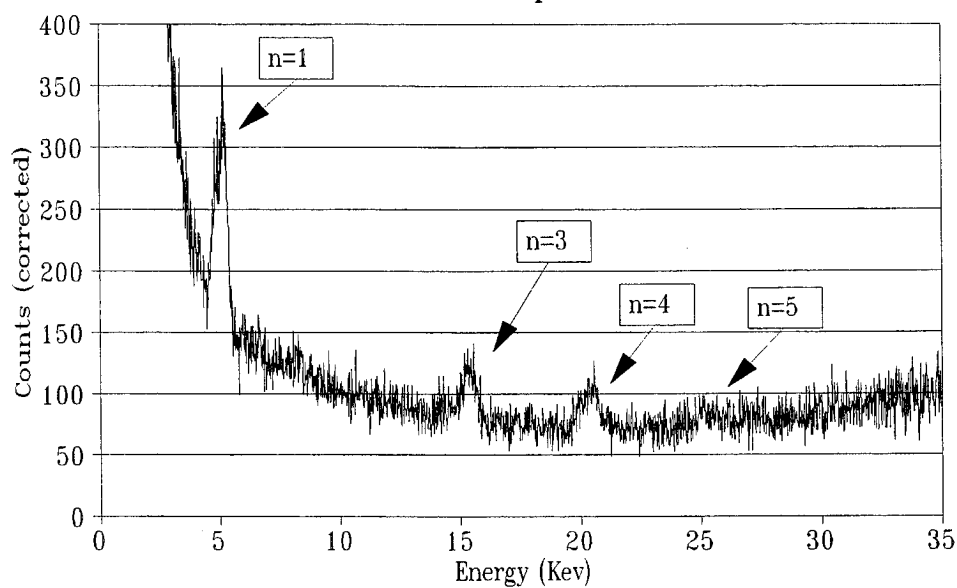
Figure 16. Typical corrected PXR spectrum of a 1.75 mm Silicon Crystal, $E_B = 100$ MeV, $\theta_B = 22.5°$. This is the same data as Figure 11, after attenuation corrections have been completed.

VI. SILICON CRYSTAL RESULTS

A.   ENERGY PEAKS

1.   1.75 mm Thick Crystal

The energy of observed PXR peaks is given by Equation 5. The 1.75 mm thick silicon monochromator has a crystal plane spacing of 0.313 nm in the $<111>$ orientation [Ref. 19]. For all experiments, θ_B is 22.5 degrees. The theoretical and observed peak energies are compared in Table 4. The n=2 peak was not observed and

Peak n=	Theoretical Energy(keV)	25 Sep 92 Energy(keV)	29-30 Sep 92 Energy(keV)	2 Dec 92 Energy(keV)
1	5.18	5.14 ±.09	5.09 ±.20	5.43 ±.25
2	10.37			
3	15.55	15.48 ±.09	15.36 ±.20	15.76 ±.25
4	20.74	20.56 ±.09	20.40 ±..20	21.02 ±.25
5	25.92	25.49 ±.15	25.28 ±.20	26.33 ±.25

Table 4. 1.75 mm Thick Silicon Crystal PXR Energy Peaks.

should not be observed as it is a forbidden transition in this crystal orientation. The observed energy peaks are close to the predicted values. The uncertainties shown in the table are the larger of either the standard error of the energy calibration linear regression calculation or the standard error of the location of the peak as determined by Peakfit. The energy values observed during the 2 December run fall outside of the predicted values. Working Equation 5 in reverse yields a $\theta_B = 22.2°$ for the 2 December data

collection run. This error in the actual θ_B was caused by the inability to know the exact position of the electron beam due to the failure of the electron gun which resulted in this run being conducted using dark current only. In a dark current condition the electron beam position must be estimated since the beam does not have enough current to cause the phosphor alignment screens to fluoresce brightly enough for the alignment cameras to detect. For a 1.75 mm thick silicon crystal the observed energy peaks were in good agreement with the predicted peaks.

2. Thin Crystal

Previously analyzed thin silicon crystal data [Ref. 5] was re-examined using the same data analysis programs as the thick crystals so meaningful intensity comparisons could be made. Thin crystal observed peak energies are compared to theoretical energy and the averaged observed energy for the 1.75 mm thick crystal in Table 5.

Peak n=	Theoretical Energy(keV)	1.75 mm thick Energy (keV)	320 μm thick Energy (keV)	44 μm thick Energy (keV)	20 μm thick Energy (keV)
1	5.18	5.11 ±.005	5.19 ±.004	4.94 ±.003	5.26 ±.001
2	10.37				
3	15.55	15.42 ±.03	16.69 ±.02	16.38 ±.05	16.05 ±.05
4	20.74	20.50 ±.04	22.49 ±.03	22.25 ±.15	21.51 ±.09
5	25.92	25.48 ±.15	28.24 ±.11	NO	NO

Table 5. 1.75 mm and Thin Silicon Crystal PXR Energy Peaks.

The energy peaks observed in the re-examined thin crystal trials did not match the theoretical values. The discrepancies exist for a number of different reasons. In the 320 μm case the ΔE between orders = 5.75 keV indicating that $\theta_B \approx 20.2°$. Similarly in the 44 μm case the ΔE = 5.87 keV indicating a $\theta_B \approx 19.8°$. In both cases n=1 peak is not

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seen at the expected energy indicating there may be a problem with the calibration run. This data was taken using a titanium and copper calibration foil stack which has calibration peaks at 4.5 keV, 8.04 keV and 8.94 keV, which does not cover the whole range of data. This data also was taken with a different detector. When Peakfit was used to analyze the calibration files the titanium linewidth between the Ortec detector (thin data) and the Canberra detector (1.75 mm data) was about twice as wide indicating that the energy of the Ortec detector may drift slightly during these trials. The 20 μm data has a $\Delta E = 5.46$ keV indicating a $\theta_B \approx 21.3°$. The 20 μm n=1 peak is where it was expected indicating that the calibration run in this case was accurate. The n=2 peak was not observed since it is a forbidden transition. The variation in the position of the energy peaks seems to have been caused by the electron beam not passing through the center of the target. In the thin crystal trials the crystal was rocked until the maximum PXR was observed. This rocking, combined with beam alignment, changed the θ_B which was being observed. This different θ_B, for different runs, makes the comparison of peak energies between runs not meaningful, however the comparison of intensity ratios should not be affected since the true PXR spectrum was being observed in all cases. It should be noted that to make meaningful comparisons between peak energies of different crystal thicknesses it is vital that the beam be accurately aligned with the crystal and detector so θ_B is identical in all cases.

B. PEAK INTENSITY RATIOS

Theoretical intensity ratios were calculated using Equation 21. The absorption length, L_a was determined by using the density [Ref. 20], and the photon attenuation coefficient μ determined by XCOM [Ref. 17], using

$$L_a = \frac{1}{\mu\rho}. \tag{29}$$

The theoretical and observed intensity ratios for the 1.75 mm thick silicon crystal are compared in Table 6 and Figure 17. The uncertainties in the intensity ratios were

Peak Ratio	Theoretical Ratio	Observed 25 Sep 92	Observed 29-30 Sep 92	Observed 02 Dec 92	Average
3-1	.88	.40 ±.03	.31 ±.02	.45 ±.02	.39±.03
4-1	.71	.28 ±.03	.32 ±.02	.42 ±.03	.34±.03
5-1	.49	.13 ±.04	.13 ±.02	.11 ±.03	.12±.04
4-3	.81	.70 ±.09	1.03 ±.08	.93 ±.08	.89±.09
5-3	.55	.33 ±.09	.42 ±.06	.24 ±.06	.33±.09
5-4	.69	.46 ±.13	.41 ±.06	.26 ±.07	.38±.13

Table 6. 1.75 mm Thick Silicon PXR Peak Intensity Ratios.

determined by calculating the uncertainty in the area for each peak using data from the Peakfit numerical summary and then adding the fractional uncertainty for the peaks in question. [Ref. 21] The ratios observed during the three 1.75 mm thick silicon crystal runs are consistent with each other but do show some significant differences with the expected theoretical calculations.
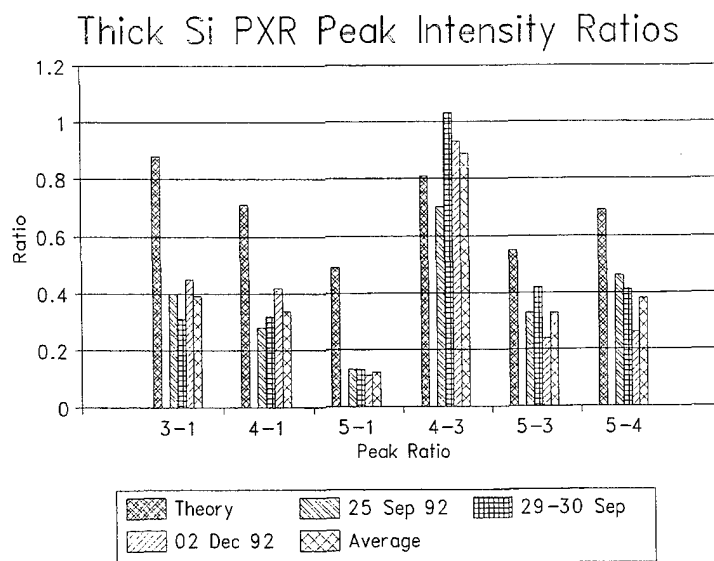
Figure 17. 1.75 mm Thick Silicon Peak Intensity Ratios.

Peak intensity ratios for the thin crystal runs also show some disparity between the expected values and the observed results. The intensity ratios are compared in the Tables 7 and 8 and Figures 18 and 19. The ratios observed here are close to the theoretical values for the thinner crystals (44 μm and 20 μm), however the observed ratios are smaller than expected for the thicker crystals (320 μm and 1.75 mm). It appears that the thicker the crystal the more the intensity ratios diverge from the current PXR theory. One factor that may be causing this divergence from theory is attenuation of the lower order PXR that is generated deep in the crystal as it travels to the surface.

Peak Ratio	1.75 mm SA		320 μm SA		44 μm SA		20 μm SA	
	Theory	Obsvd	Theory	Obsvd	Theory	Obsvd	Theory	Obsvd
3-1	.88	.39±.03	.45	.32±.01	.090	.057±.01	.059	.031±.01
4-1	.71	.32±.03	.23	.23±.01	.040	.030±.01	.025	.014±.01
5-1	.49	.12±.02	.12	.05±.01				
4-3	.81	.89±.09	.51	.71±.04	.44	.53±.15	.42	.45±.11
5-3	.55	.33±.09	.27	.16±.03				
5-4	.69	.38±.13	.52	.22±.05				

Table 7. 1.75 mm and Thin Silicon PXR Peak Intensity Ratios.

Peak Ratio	1.75 mm SA Obsvd/Theory	320 μm SA Obsvd/Theory	44 μm SA Obsvd/Theory	20 μm SA Obsvd/Theory
3-1	.44	.71	.63	.53
4-1	.45	1.00	.75	.56
5-1	.24	.42		
4-3	1.01	1.39	1.20	1.07
5-3	.60	.59		
5-4	.55	.42		

Table 8. Ratios of observed PXR ratios compared to theoretical PXR ratios.
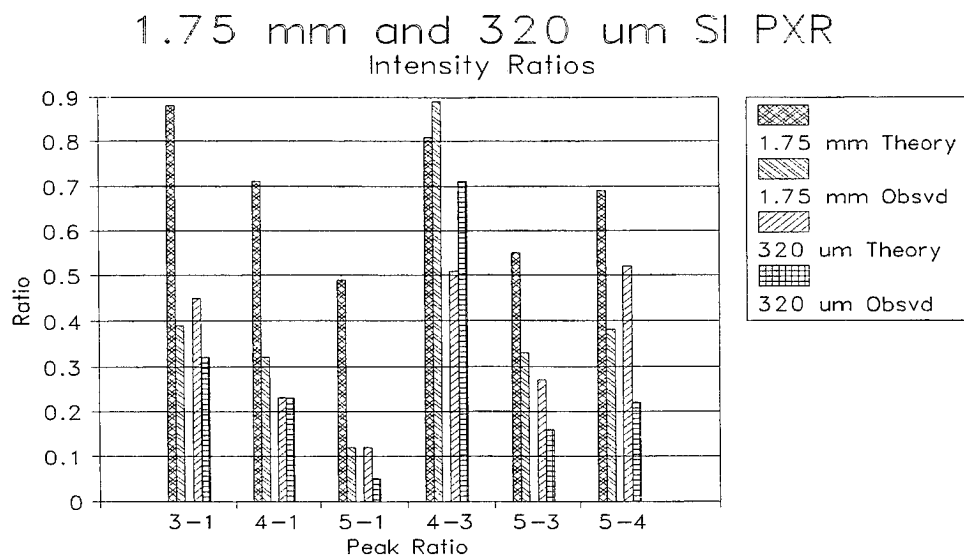
Figure 18. 1.75 mm and 320 μm Silicon Peak Intensity Ratios

Figure 19. 44 μm and 20 μm Silicon Peak Intensity Ratios

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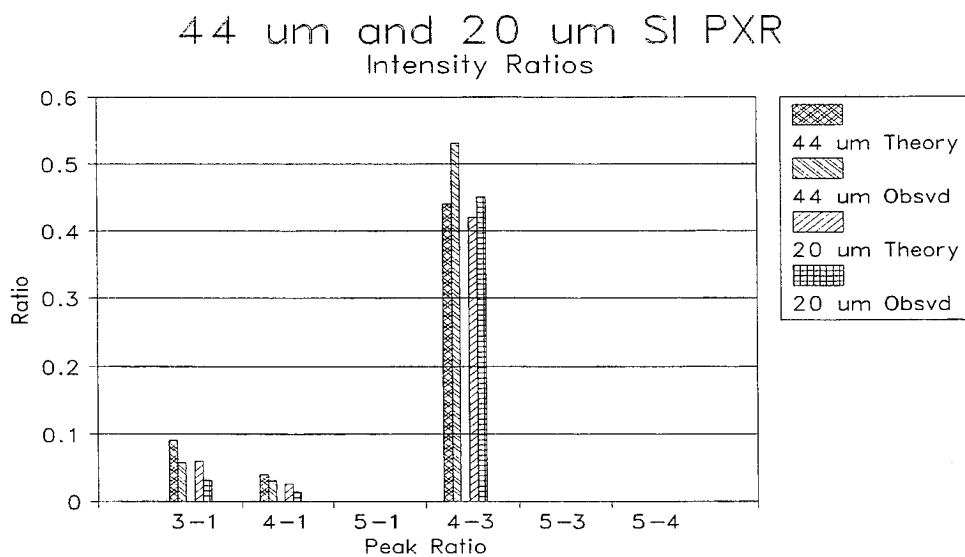
VII. LITHIUM FLUORIDE CRYSTAL RESULTS

A. ENERGY PEAKS

The theoretical energy of observed PXR peaks is given by Equation 5. The 1 mm thick lithium fluoride monochromator has a crystal plane spacing of 0.1424 nm in the <220> orientation [Ref. 19]. For our experiment, the Bragg angle was, $\theta_B = 22.5°$. The theoretical and observed peak energies are compared in Table 9. The uncertainties listed in the table are the standard error of the energy calibration linear regression calculation. In all cases, the uncertainty of the energy calibration is larger than the uncertainty, determined by Peakfit, in the location of the particular energy peaks. The measured energy peaks are in good agreement with the expected results. The reduced electron beam energy during the 3 December data collection run seems to have had no effect on the energy peaks, thus confirming the geometrical interpretation of PXR as the scattering of virtual photons.

Peak n=	Theoretical Energy (keV)	22 Oct 92 (95 MeV Beam) Energy (keV)	01 Dec 92 (92 MeV Beam) Energy (keV)	03 Dec 92 (62 MeV Beam) Energy (keV)
1	11.4	11.2 ±0.13	11.4 ±0.14	11.3 ±0.3
2	22.8	22.3 ±0.13	23.0 ±0.14	23.0 ±0.3

Table 9. Lithium Fluoride Crystal PXR Energy Peaks.

B. PEAK INTENSITY RATIOS

As with the silicon data, the peak intensity ratios for lithium fluoride were calculated using Equation 21. The absorption length, L_a was determined by using the density [Ref. 20], and the photon attenuation coefficient μ determined by XCOM [Ref. 17], using Equation 29. The theoretical and observed intensity ratios are compared in Table 10. The uncertainties in the intensity ratios were determined by calculating the uncertainty in the area for each peak using data from the Peakfit numerical summary and then adding the fractional uncertainty for the peaks in question [Ref. 21]. The peak intensity ratio observed on 01 December, where the data is of much better quality, is in agreement with the calculated theoretical ratio. The uncertainties in the 22 October and the 03 December data are greater than 100% due to the small size of the n=2 peak in these data sets as seen in Appendices E5 and E6. Due to these large uncertainties the peak intensity ratios for the 22 October and 03 December data runs should be disregarded.

Peak Ratio	Theoretical Ratio	Observed 01 Dec 92 (92 MeV Beam)	Observed 22 Oct 92 (95 MeV Beam)	Observed 03 Dec 92 (62 MeV Beam)
2-1	.19	.186±.03	.082±.1	.025±.1

Table 10. Lithium Fluoride PXR Peak Intensity Ratios.

C.   40 keV BACKGROUND DIP

An unexpected result was seen during all three data collection runs with the lithium fluoride crystal. As shown in Figure 20 and Appendices E4, E5 and E6, at about
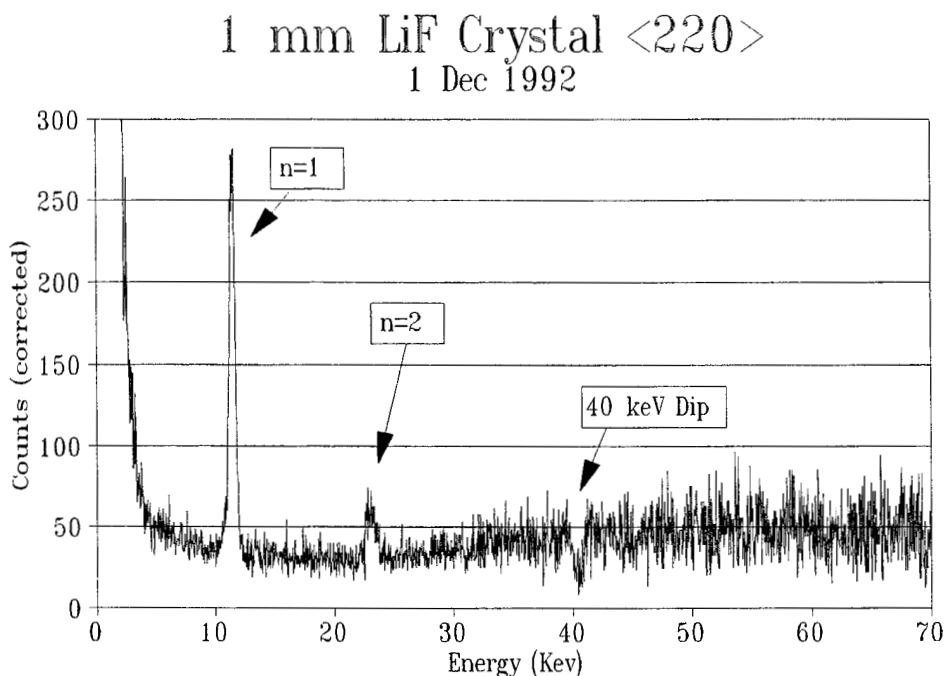
Figure 20. 40 keV background dip observed during Lithium Fluoride data collection runs.

40 keV a dip in the background was seen. This dip in the background was not observed during the silicon crystal data collection runs with the same experimental setup. The cause of this dip is an issue that remains open for exploration. It does not correspond to the energy of any known x-ray line. For now, it is an experimental anomaly.

VIII. CONCLUSIONS

Predicted PXR energy peak calculations are in good agreement with the observed peaks for silicon and for lithium fluoride.

Calculated PXR peak intensity ratios for silicon are not in agreement with the observed experimental results for thick silicon crystals (1.75 mm and 320 μm). The observed results for thin crystals (44 μm and 20 μm), are generally in agreement with the theory. The ratios observed in the 20 μm case are very close to the expected results. One factor that may be causing the observed divergence from theory is attenuation of the lower order PXR that is generated deep in the crystal as it travels to the surface. Predicted PXR peak intensity ratios for lithium fluoride are in agreement with the peak ratios observed in the 1 mm thick lithium fluoride crystal.

The appearance of the 40 keV dip in the background during the lithium luoride runs is puzzling. A brief search for an explanation failed to yield an answer and further exploration is required.

This experiment is the first observation of parametric x-radiation using lithium fluoride as a target. Due to the small spacing between the crystal planes the LiF PXR first order peak is above 10 keV. LiF shows promise as a source of high energy x-rays when compared to PXR from silicon.

IX. RECOMMENDATIONS

A. PXR EXPERIMENTS

Further exploration of PXR is certainly needed. The first step would seem to be analysis of different thicknesses of silicon crystals to resolve both the thin crystal energy peak question and to further explore the intensity ratio problem. As shown with lithium fluoride data can be taken at different beam energies using the NPS LINAC. This data might help to resolve some of the apparent differences between theory and practice.

Further data using the lithium fluoride crystal is also a logical next step. With longer data collection runs higher order peaks should be detectable and the 40 keV dip needs exploration.

Future PXR experiments could also include different crystal monochromators. Many suitable crystals are available, including quartz, indium antimonide, and germanium [Ref. 19].

B. EQUIPMENT

There were some equipment limitations encountered during this research. The power and stability problems of the LINAC probably require a general overhaul and tune up. Observed background radiation could probably be reduced with tighter radio frequency shielding of the accelerator end station and klystron gallery to eliminate as much klystron noise as possible.

Long range improvements which would aid in the further exploration of PXR would be a faster detector so data runs could be conducted at higher beam currents without double counting and a detector that has a wider range of energies which it can detect.

APPENDIX A. ENERGY CALIBRATION SPECTRUMS

This appendix contains the as collected energy calibration spectrums as well as the Peakfit graphical and numerical analysis of the calibration peaks and concludes with the data and linear regression used to calculate the energy calibration.

Section	Date	Beam Energy	Calibration	Target
A1	25 Sep 92	96 MeV	Tri Foil	Thick Si
A2	29-30 Sep 92	96 MeV	Tri Foil	Thick Si
A3	02 Dec 92	91 MeV	Tri Foil	Thick Si
A4	01 Dec 92	92 MeV	Tri Foil	LiF
A5	03 Dec 92	62 MeV	Tri Foil	LiF
A6	22 Oct 92	95 MeV	Tri Foil	LiF
A7	05 Sep 91	85 MeV	Ti,Cu Foil	Thin Si
A8	23 Jul 91	85 MeV	Ti,Cu Foil	Thin Si

Table 11. Energy Calibration Runs.

Sections A7 and A8 are calibration data used to analyze the thin silicon PXR spectrums reported on in Reference 5.

A1. ENERGY CALIBRATION DATA TAKEN ON 25 SEPTEMBER 1992

25 Sep 92 Tri–Foil Calibration

25 Sep 92 Tri–Foil Calibration
Gauss1(39.7505, 264.404, 5.65319)
Exp2(3.11373, 436.855) Gauss3(50.8793, 817.339, 7.37403)
Gauss4(10.3527, 912.918, 8.84443) Gauss5(5.98968, 1359.77, 11.0592)
Bkgnd(0.943939) X2=4882.7997 r2=0.91316779
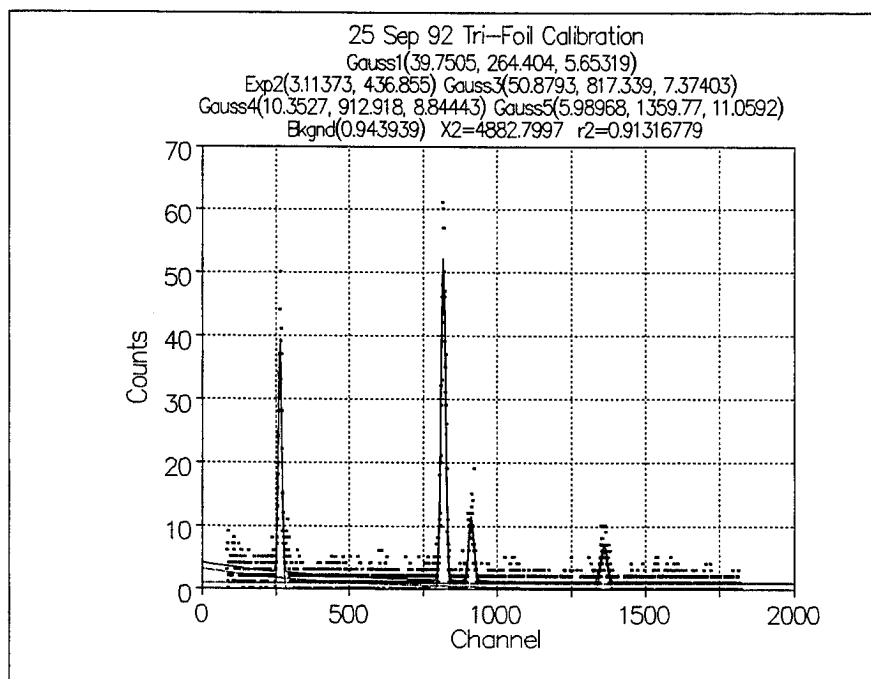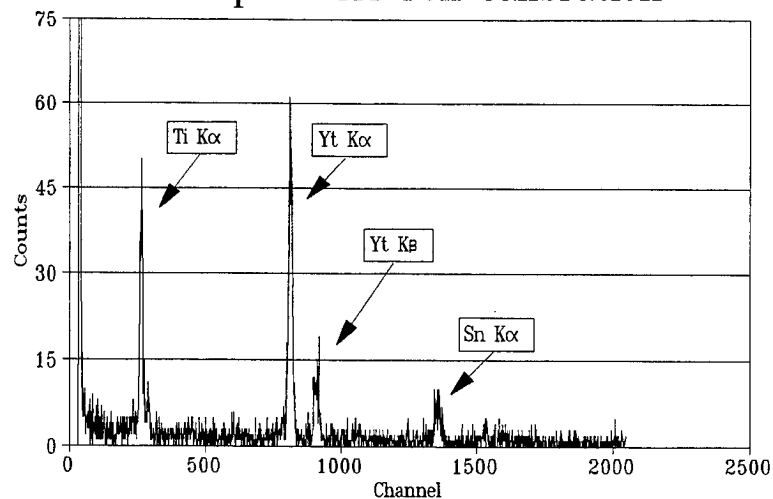
```
                        PeakFit Numerical Summary
Description: 25 Sep 92 Tri-Foil Calibration
X-Y Table Size: 2049    Active Points: 1740
X Variable: Channel
Y Variable: Counts
File Source: CAL925X4.PRN


Curve-Fit Std Error= 1.68244124    r2= 0.913167787


Background Coefficients [y=a+bx+cx^2+dx^3]
Background        a           b           c           d
      Order= 0    0.9439394


Curve-Fit Coefficients
Peak#  Type      Ampl        Ctr         Wid1        Wid2        Wid3
  1   Gaussian   39.75051    264.4044    5.6531916
  2   Exp        3.1137273   436.85481
  3   Gaussian   50.879296   817.33949   7.3740329
  4   Gaussian   10.352699   912.91836   8.8444305
  5   Gaussian   5.9896774   1359.7728   11.059184


Measured Values
Peak#  Type      PkAmpl      PkCtr       Wid@HM      Area        %Area
  1   Gaussian   39.75051    264.4044    13.312229   563.28256   29.657523
  2   Exp        0           0           0           0           0
  3   Gaussian   50.879296   817.33949   17.364475   940.4505    49.515881
  4   Gaussian   10.352699   912.91836   20.826956   229.51617   12.08431
  5   Gaussian   5.9896774   1359.7728   26.042228   166.04144   8.7422869
      Total                                          1899.2907   100


Peak# 1  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  39.75051039   264.4043968   13.31222926   563.2825625
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  257.7482841   271.0605133   6.65611269    6.656116574
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  39.75051039   0.653363159   60.83984053   38.47234391   41.02867687
   Ctr  264.4043968   0.106904515   2473.27625    264.1952607   264.6135328
  Wid1  5.65319158    0.108081629   52.30483318   5.44175279    5.864630369


Peak# 2  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  3.113727307   0.244870718   12.71580097   2.634689671   3.592764944
  Rtel  436.8548138   71.86411273   6.078900819   296.2679154   577.4417121


Peak# 3  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  50.87929618   817.3394858   17.3644747    940.4505022
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  808.6572293   826.021704    8.682256575   8.682218123
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  50.87929618   0.571491251   89.02900276   49.76129473   51.99729763
   Ctr  817.3394858   0.095385507   8568.801596   817.1528843   817.5260874
  Wid1  7.374032898   0.096149905   76.69308531   7.185935996   7.5621298


Peak# 4  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  10.35269944   912.9183567   20.82695556   229.5161726
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  902.5048714   923.3318269   10.41348536   10.4134702
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  10.35269944   0.521831497   19.83916169   9.331846763   11.37355211
   Ctr  912.9183567   0.513399098   1778.184575   911.9140003   913.9227132
  Wid1  8.84443049    0.517521786   17.08996748   7.832008852   9.856852127
```

```
Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  5.989677371   1359.772755   26.04222811   166.0414396
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  1346.751653   1372.793881   13.02110294   13.02112517
 Parm  Value         Std Error      t-value        95% Confidence Limits
 Ampl  5.989677371   0.467182583   12.82084905    5.07573371    6.903621032
  Ctr  1359.772755   0.992276138   1370.357205    1357.831578   1361.713933
 Wid1  11.05918401   1.003537468   11.0202004     9.095975746   13.02239227


Background  Order=0    Area=1641.5106393
 Parm    Value         Std Error      t-value        95% Confidence Limits
   a    0.943939413   0.104122444   9.065667064    0.740245929   1.147632897


Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 1.682441241      r2= 0.9131677868
Source    Sum of Squares     DF      Mean Square       F
Regr      51349.784          14      3667.8417         1295.78
Error     4882.7997          1725    2.8306085
Total     56232.584          1739


        25 Sep 92 Energy Calibration Linear Regression Calculation

Element   X-Ray Line Channel Energy Kev
Ti        Kα           264.404    4.507
Yt        Kα           817.339    14.926
Yt        Kß           912.918    16.874
Sn        Kα          1359.773    25.156
                Regression Output:
Constant                        -0.45769
Std Err of Y Est                 0.087221
R Squared                        0.99993
No. of Observations                     4
Degrees of Freedom                      2

X Coefficient(s)  0.018869
Std Err of Coef.  0.000112
```

A2. ENERGY CALIBRATION DATA TAKEN 29-30 SEPTEMBER 1992

29 Sep 92 Tri-Foil Calibration
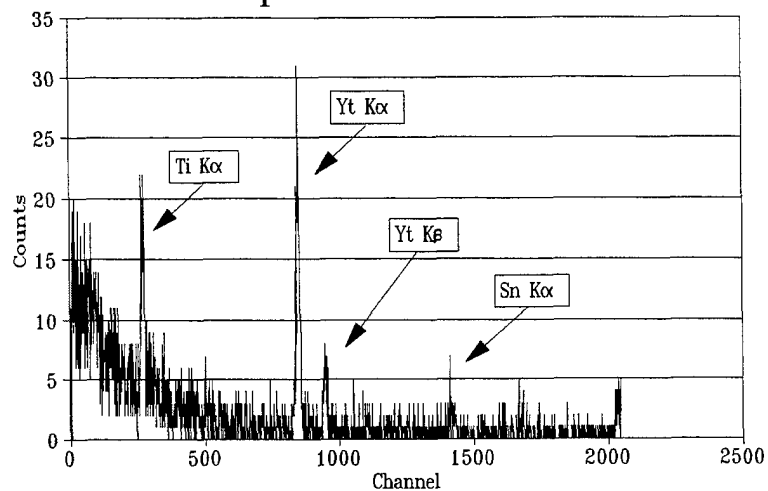
30 Sep 92 Tri-Foil Calibration
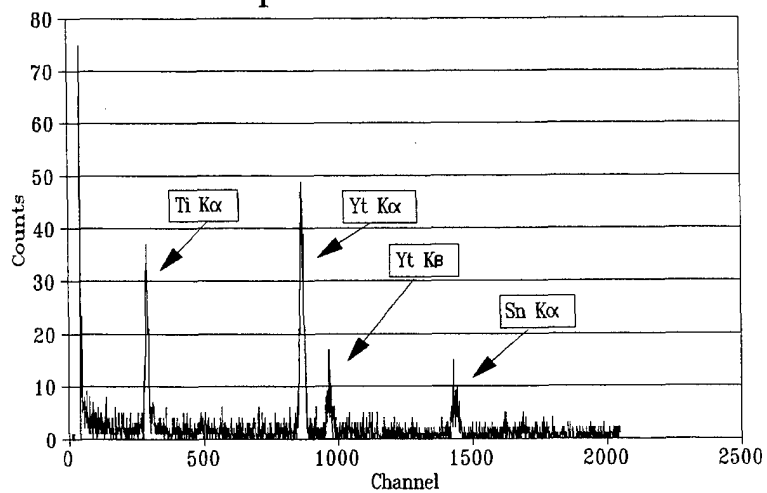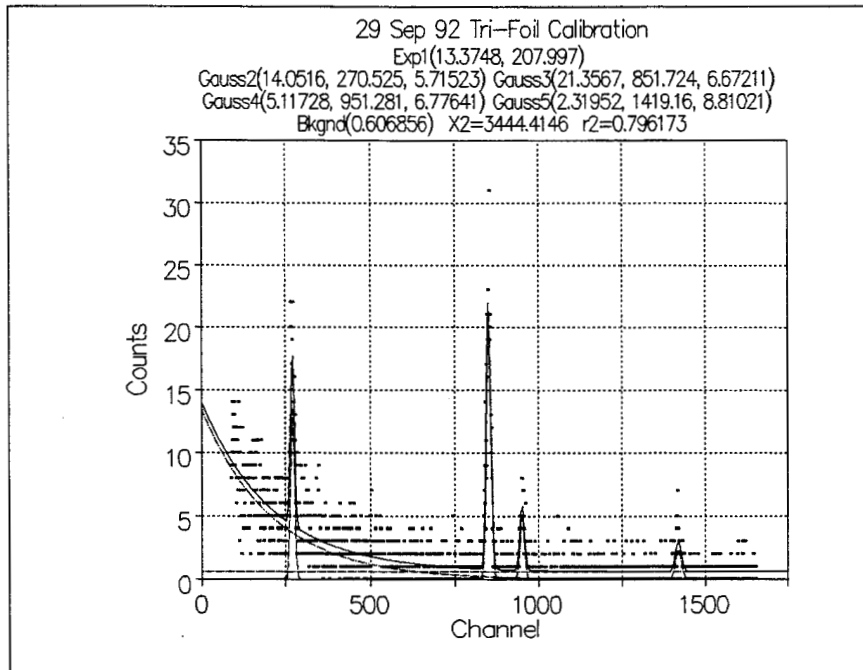
29 Sep 92 Tri-Foil Calibration
Exp1(13.3748, 207.997)
Gauss2(14.0516, 270.525, 5.71523) Gauss3(21.3567, 851.724, 6.67211)
Gauss4(5.11728, 951.281, 6.77641) Gauss5(2.31952, 1419.16, 8.81021)
Bkgnd(0.606856) X2=3444.4146 r2=0.796173

PeakFit Numerical Summary

Description: 29 Sep 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 1567
X Variable: Channel
Y Variable: Counts
File Source: CAL929X3.PRN

Curve-Fit Std Error= 1.4897447   r2= 0.796173001

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	0.6068557			

Curve-Fit Coefficients

Peak#	Type	Ampl	Rte1	Amp2	Rte2
1	Exp	13.374803	207.99687		
2	Gaussian	14.051629	270.52525	5.7152349	
3	Gaussian	21.356656	851.7238	6.6721124	
4	Gaussian	5.1172806	951.28139	6.7764128	
5	Gaussian	2.3195225	1419.1646	8.8102087	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Gaussian	14.051629	270.52525	13.458337	201.30322	28.89673
3	Gaussian	21.356656	851.7238	15.711563	357.18045	51.272637
4	Gaussian	5.1172806	951.28139	15.957158	86.921956	12.477497
5	Gaussian	2.3195225	1419.1646	20.746413	51.224134	7.353136
	Total				696.62975	100

Peak# 1 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	13.37480346	0.483859262	27.6419292	12.42784531	14.32176161
Rte1	207.9968723	8.842537005	23.52230725	190.6911946	225.3025501

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```
Peak# 2  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  14.05162926   270.5252467    13.45833709   201.3032188
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  263.7960806   277.2544177    6.729166082   6.729171013
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  14.05162926    0.576342916    24.38067489    12.92367189   15.17958663
  Ctr   270.5252467    0.269251155    1004.731983    269.9982968   271.0521965
  Widl  5.715234918    0.273520137    20.89511577    5.179930249   6.250539587

Peak# 3  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  21.35665575   851.7237967    15.71156272   357.1804461
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  843.8680257   859.5795884    7.855771043   7.855791674
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  21.35665575    0.531485191    40.18297428    20.31648917   22.39682232
  Ctr   851.7237967    0.191399293    4449.984025    851.3492103   852.0983831
  Widl  6.672112359    0.192392143    34.67975484    6.295582814   7.048641904

Peak# 4  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  5.117280555   951.2813873    15.95715792   86.92195628
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  943.3027745   959.2599325    7.978612731   7.978545187
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  5.117280555    0.527494495    9.701107032    4.084924145   6.149636965
  Ctr   951.2813873    0.805010463    1181.70065     949.705906    952.8568686
  Widl  6.776412797    0.809714365    8.368892901    5.191725521   8.361100074

Peak# 5  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  2.319522503   1419.164563    20.7464125    51.22413363
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  1408.79135    1429.537763    10.3732124    10.3732001
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  2.319522503    0.46339536     5.005493583    1.412614137   3.22643087
  Ctr   1419.164563    2.025041829    700.8075304    1415.201365   1423.12776
  Widl  8.810208686    2.047021865    4.303915282    4.803994093   12.81642328

Background  Order=0    Area=950.33608736
  Parm    Value         Std Error      t-value        95% Confidence Limits
  a      0.606855739   0.058030407    10.45754746    0.493284766   0.720426712

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 1.489744704      r2= 0.7961730012
Source   Sum of Squares    DF      Mean Square        F
Regr     13454.301         14      961.02153          433.021
Error    3444.4146         1552    2.2193393
Total    16898.716         1566
```

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30 Sep 92 Tri-Foil Calibration
Gauss1(31.7272, 287.728, 5.50182)
Exp2(2.00643, 419.647) Gauss3(41.3076, 869.738, 7.33944)
Gauss4(8.12898, 970.7, 7.73508) Gauss5(5.79659, 1438.92, 11.1422)
Bkgnd(0.941363) X2=3978.6336 r2=0.89160493
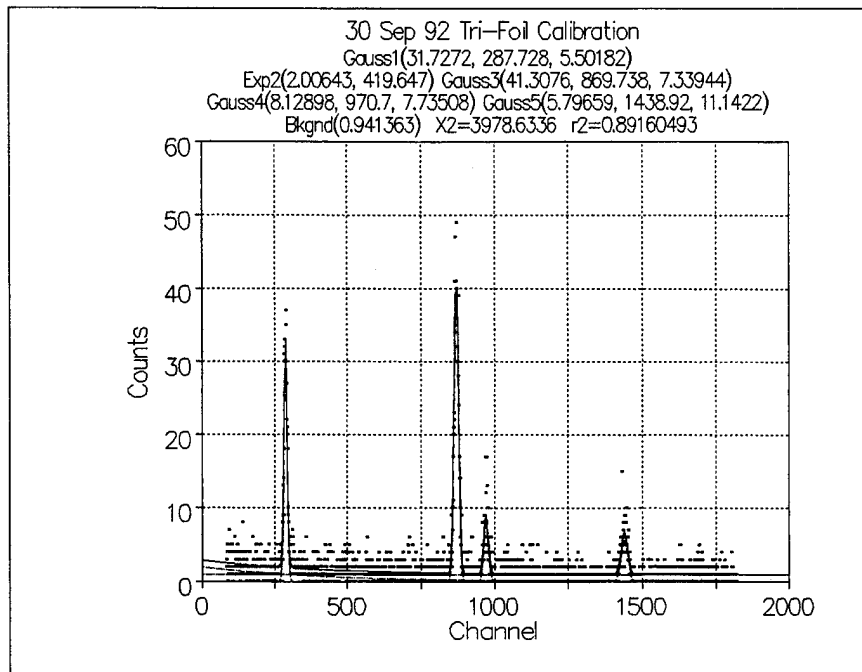
PeakFit Numerical Summary

Description: 30 Sep 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 1740
X Variable: Channel
Y Variable: Counts
File Source: CAL930X4.PRN

Curve-Fit Std Error= 1.5187015   r2= 0.891604928
Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	0.9413625			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	31.727207	287.72831	5.5018151		
2	Exp	2.0064313	419.64714			
3	Gaussian	41.307595	869.73784	7.3394399		
4	Gaussian	8.1289771	970.70035	7.7350831		
5	Gaussian	5.7965891	1438.9181	11.142206		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	31.727207	287.72831	12.955757	437.55008	28.843071
2	Exp	0	0	0	0	0
3	Gaussian	41.307595	869.73784	17.283023	759.94444	50.095137
4	Gaussian	8.1289771	970.70035	18.214672	157.6128	10.389753
5	Gaussian	5.7965891	1438.9181	26.237758	161.89509	10.672039
	Total				1517.0024	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
31.72720656	287.7283123	12.95575696	437.5500831

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
281.250434	294.206191	6.477878312	6.477878649

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	31.72720656	0.597588102	53.09209882	30.55815215	32.89626097
Ctr	287.7283123	0.119272161	2412.367732	287.4949816	287.961643
Wid1	5.501815083	0.120438597	45.68149418	5.266202505	5.737427661

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```
Peak# 2  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  2.006431324   0.227148763   8.833115793    1.562062934   2.450799713
  Rtel  419.6471406   95.72628176   4.383823678    232.3789683   606.9153129

Peak# 3  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  41.30759514   869.7378358   17.28302328   759.9444398
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  861.0963209   878.3793441   8.641514963   8.641508318
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  41.30759514   0.516896941   79.91456684    40.29639588   42.3187944
  Ctr   869.7378358   0.105804763   8220.21442     869.5308512   869.9448204
  Widl  7.339439941   0.106536923   68.89104481    7.131023041   7.54785684

Peak# 4  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  8.128977082   970.700355    18.21467154   157.6127994
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  961.5930426   979.8077141   9.107312371   9.107359174
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  8.128977082   0.50339234    16.14839249    7.144196709   9.113757455
  Ctr   970.700355    0.551951318   1758.670235    969.6205792   971.7801307
  Widl  7.735083104   0.555404828   13.9269281     6.648551328   8.821614881

Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  5.796589125   1438.918129   26.23775751   161.8950935
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  1425.799274   1452.037031   13.11885521   13.1189023
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  5.796589125   0.420403605   13.78815277    4.974158615   6.619019634
  Ctr   1438.918129   0.929005811   1548.879579    1437.100726   1440.735532
  Widl  11.14220624   0.941284019   11.83724148    9.300783642   12.98362883

Background  Order=0    Area=1637.029426
  Parm    Value         Std Error     t-value        95% Confidence Limits
  a       0.941362522   0.090308527   10.42384976    0.764693037   1.118032007

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 1.518701504      r2= 0.8916049276
Source    Sum of Squares    DF      Mean Square      F
Regr      32726.297         14      2337.5926        1013.5
Error     3978.6336         1725    2.3064543
Total     36704.93          1739
```

29 Sep 92 Energy Calibration Linear Regression Calculation

Element	X-Ray Line	Channel	Energy Kev
Ti	Kα	270.525	4.507
Yt	Kα	851.724	14.926
Yt	Kß	951.281	16.874
Sn	Kα	1419.165	25.156
Ti	Kα	287.728	4.507
Yt	Kα	869.738	14.926
Yt	Kß	970.7	16.874
Sn	Kα	1438.918	25.156

```
                Regression Output:
Constant                      -0.48599
Std Err of Y Est               0.20424
R Squared                      0.999421
No. of Observations            8
Degrees of Freedom             6
X Coefficient(s)  0.017963
Std Err of Coef.  0.000176
```

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02 Dec 92 Tri–Foil Calibration
Prior to Data Run
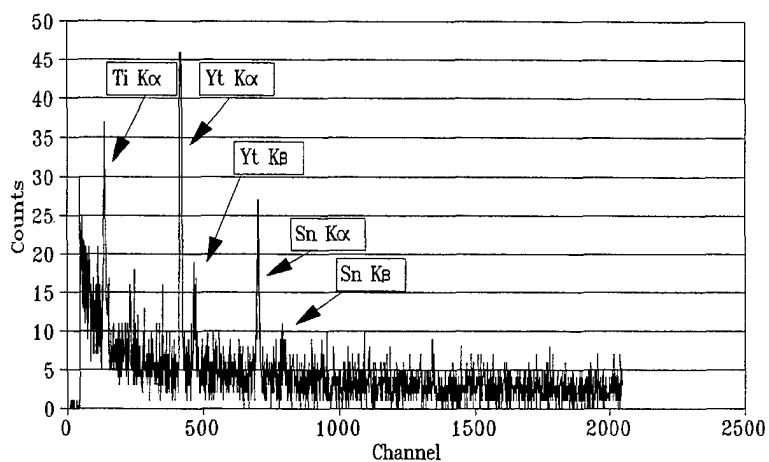
02 Dec 92 Tri–Foil Calibration
After Data Run
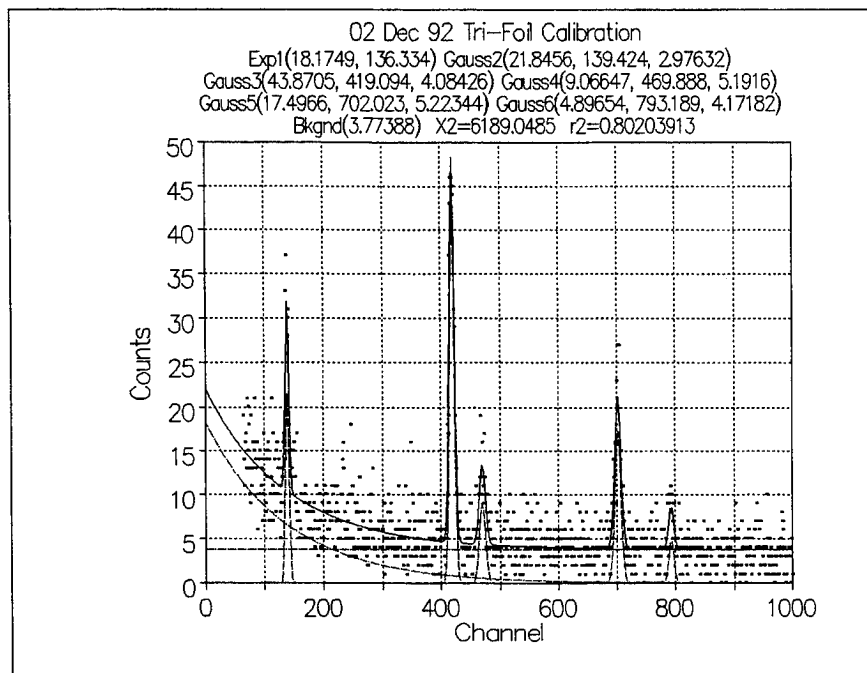
60

02 Dec 92 Tri-Foil Calibration
Exp1(18.1749, 136.334) Gauss2(21.8456, 139.424, 2.97632)
Gauss3(43.8705, 419.094, 4.08426) Gauss4(9.06647, 469.888, 5.1916)
Gauss5(17.4966, 702.023, 5.22344) Gauss6(4.89654, 793.189, 4.17182)
Bkgnd(3.77388) X2=6189.0485 r2=0.80203913

PeakFit Numerical Summary

Description: 02 Dec 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 936
X Variable: Channel
Y Variable: Counts
File Source: CM1202X2.PRN

Curve-Fit Std Error= 2.5965136   r2= 0.802039129

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	3.7738825			

Curve-Fit Coefficients

Peak#	Type	Amp1	Rte1	Amp2	Rte2
1	Exp	18.174903	136.33402		
2	Gaussian	21.845597	139.4237	2.9763176	
3	Gaussian	43.870546	419.09413	4.0842593	
4	Gaussian	9.0664736	469.888	5.1916002	
5	Gaussian	17.496633	702.0232	5.2234369	
6	Gaussian	4.8965373	793.18865	4.1718216	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Gaussian	21.845597	139.4237	7.0086881	162.97956	16.130332
3	Gaussian	43.870546	419.09413	9.6176818	449.13525	44.451591
4	Gaussian	9.0664736	469.888	12.225253	117.98575	11.677228
5	Gaussian	17.496633	702.0232	12.300189	229.08713	22.673098
6	Gaussian	4.8965373	793.18865	9.8238183	51.204144	5.0677511
	Total				1010.3918	100

```
Peak# 1   Exp
  PkAmpl         PkCtr          Wid@HM         Area
  0              0              0              0
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  0              0              0              0
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  18.17490324    1.187089105    15.31047936   15.84759982   20.50220667
  Rtel  136.334023     9.966010967    13.67989895   116.7955306   155.8725154

Peak# 2   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  21.84559705    139.4237025    7.008688131    162.979562
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  135.9193567    142.9280448    3.504345835    3.504342296
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  21.84559705    1.3913451      15.70106299   19.11784713   24.57334698
   Ctr  139.4237025    0.217846434    640.0091101   138.9966118   139.8507932
  Widl  2.976317623    0.22101011     13.46688446   2.543024464   3.409610781

Peak# 3   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  43.87054597    419.0941334    9.617681847    449.1352494
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  414.2852962    423.902978     4.808837218    4.80884463
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  43.87054597    1.184535873    37.03606363   41.54824819   46.19284375
   Ctr  419.0941334    0.127059726    3298.402612   418.8450311   419.3432356
  Widl  4.084259304    0.12789628     31.93415235   3.833517004   4.335001603

Peak# 4   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  9.066473588    469.8879984    12.22525335    117.9857536
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  463.7753813    476.0006346    6.112617181    6.112636169
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  9.066473588    1.050838079    8.627850257   7.006292046   11.12665513
   Ctr  469.8879984    0.693170087    677.8826835   468.5290296   471.2469673
  Widl  5.191600206    0.698117819    7.436567392   3.822931261   6.56026915

Peak# 5   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  17.49663278    702.0231986    12.30018876    229.0871267
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  695.8731172    708.1733059    6.150081375    6.150107382
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  17.49663278    1.048459578    16.68794215   15.44111432   19.55215124
   Ctr  702.0231986    0.360282405    1948.535897   701.3168603   702.7295368
  Widl  5.223436929    0.363709891    14.36154764   4.510379019   5.93649484

Peak# 6   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  4.89653725     793.18865      9.823818317    51.20414359
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  788.276747     798.1005653    4.911902991    4.911915326
  Parm  Value          Std Error      t-value       95% Confidence Limits
  Ampl  4.89653725     1.17282562     4.174991717   2.597197568   7.195876932
   Ctr  793.18865      1.150514682    689.420711    790.9330512   795.4442488
  Widl  4.1718216      1.160410625    3.595125303   1.896821674   6.446821525

Background  Order=0    Area=3528.5801517
  Parm   Value          Std Error      t-value       95% Confidence Limits
   a     3.773882515    0.137809808    27.38471645   3.503704618   4.044060413

Total Peaks= 6   Coefficient Count= 18   Fitted Count=18
Std Error for Curve= 2.596513598     r2= 0.8020391287
Source    Sum of Squares    DF      Mean Square     F
Regr      25074.95          17      1474.9971       218.781
Error     6189.0485         918     6.7418829
Total     31263.999         935
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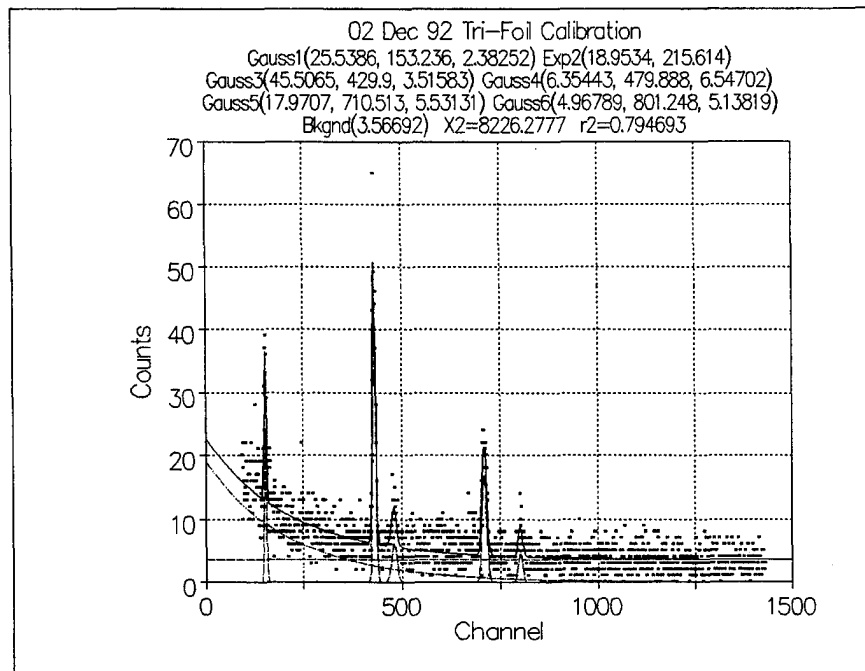
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02 Dec 92 Tri-Foil Calibration
Gauss1(25.5386, 153.236, 2.38252) Exp2(18.9534, 215.614)
Gauss3(45.5065, 429.9, 3.51583) Gauss4(6.35443, 479.888, 6.54702)
Gauss5(17.9707, 710.513, 5.53131) Gauss6(4.96789, 801.248, 5.13819)
Bkgnd(3.56692) X2=8226.2777 r2=0.794693

PeakFit Numerical Summary

Description: 02 Dec 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 1336
X Variable: Channel
Y Variable: Counts
File Source: CM1202X3.PRN

Curve-Fit Std Error= 2.49829649   r2= 0.794693002

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	3.5669181			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	25.538596	153.23611	2.3825152		
2	Exp	18.953434	215.61415			
3	Gaussian	45.506535	429.90035	3.5158277		
4	Gaussian	6.3544321	479.88818	6.5470224		
5	Gaussian	17.970671	710.51314	5.5313125		
6	Gaussian	4.9678881	801.24796	5.1381925		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	25.538596	153.23611	5.6103753	152.51853	15.707532
2	Exp	0	0	0	0	0
3	Gaussian	45.506535	429.90035	8.2791066	401.04333	41.302528
4	Gaussian	6.3544321	479.88818	15.417031	104.2822	10.739784
5	Gaussian	17.970671	710.51314	13.025187	249.16197	25.660617
6	Gaussian	4.9678881	801.24796	12.099487	63.983743	6.5895382
	Total				970.98978	100

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```
Peak# 1  Gaussian
  PkAmpl         PkCtr        Wid@HM        Area
  25.53859583  153.2361059  5.610375343  152.5185315
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  150.4309182  156.0412936  2.805187689  2.805187655
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  25.53859583  1.496154022  17.06949649  22.60875969  28.46843196
  Ctr  153.2361059  0.160403909  955.3140373  152.9219957  153.5502161
 Widl  2.382515224  0.162714026  14.64234697  2.063881296  2.701149151

Peak# 2  Exp
  PkAmpl         PkCtr        Wid@HM        Area
  0            0            0            0
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  0            0            0            0
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  18.95343421  0.875002421  21.66100773  17.23996509  20.66690332
 Rtel  215.6141482  11.89380562  18.12827239  192.3231628  238.9051336

Peak# 3  Gaussian
  PkAmpl         PkCtr        Wid@HM        Area
  45.50653546  429.9003537  8.279106552  401.0433287
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  425.7607952  434.0399018  4.139558486  4.139548066
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  45.50653546  1.229245791  37.01988308  43.09937103  47.91369988
  Ctr  429.9003537  0.109348501  3931.470007  429.6862226  430.1144849
 Widl  3.515827748  0.110290137  31.87798876  3.299852638  3.731802857

Peak# 4  Gaussian
  PkAmpl         PkCtr        Wid@HM        Area
  6.354432059  479.8881822  15.41703145  104.2822029
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  472.1796587  487.5966901  7.708523516  7.708507931
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  6.354432059  0.902300672  7.042477366  4.58750628   8.121357839
  Ctr  479.8881822  1.068625443  449.0705191  477.7955518  481.9808126
 Widl  6.547022407  1.083083118  6.044801454  4.426080306  8.667964508

Peak# 5  Gaussian
  PkAmpl         PkCtr        Wid@HM        Area
  17.97067085  710.5131383  13.02518729  249.1619724
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  704.0005333  717.0257205  6.512605079  6.512582213
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  17.97067085  0.978953115  18.35702914  16.05364081  19.88770089
  Ctr  710.5131383  0.347316147  2045.724464  709.8330082  711.1932684
 Widl  5.531312485  0.349168266  15.84139516  4.847555473  6.215069497

Peak# 6  Gaussian
  PkAmpl         PkCtr        Wid@HM        Area
  4.967888119  801.2479567  12.09948676  63.98374276
  XL @HM        XR @HM       Ctr-XL@HM    Ctr-XR@HM
  795.1982122  807.297699   6.049744435  6.049742326
 Parm  Value        Std Error    t-value       95% Confidence Limits
 Ampl  4.967888119  1.015510821  4.892009044  2.979269132  6.956507106
  Ctr  801.2479567  1.210896031  661.6983918  798.8767256  803.6191878
 Widl  5.138192529  1.216636131  4.223277937  2.755720909  7.520664149

Background  Order=0    Area=4761.8356232
  Parm    Value       Std Error    t-value       95% Confidence Limits
   a      3.56691807  0.113535587  31.41674057  3.344587575  3.789248565

Total Peaks= 6   Coefficient Count= 18   Fitted Count=18
Std Error for Curve= 2.498296486    r2= 0.7946930023
Source   Sum of Squares   DF    Mean Square    F
Regr     31841.902        17    1873.0531      300.097
Error    8226.2777        1318  6.2414853
Total    40068.18         1335
```

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```
      2 Dec 92 Energy Calibration Linear Regression Calculation
Element   X-Ray Line Channel  Energy Kev
Ti        Kα        139.424    4.507
Yt        Kα        419.094   14.926
Yt        Kß        469.888   16.874
Sn        Kα        702.023   25.156
Sn        Kß        793.189   28.795
Ti        Kα        153.236    4.507
Yt        Kα        429.9     14.926
Yt        Kß        479.888   16.874
Sn        Kα        710.516   25.156
Sn        Kß        801.248   28.795
           Regression Output:
Constant                     -0.85577
Std Err of Y Est              0.248394
R Squared                     0.999315
No. of Observations                 10
Degrees of Freedom                   8

X Coefficient(s)  0.037085
Std Err of Coef.  0.000343
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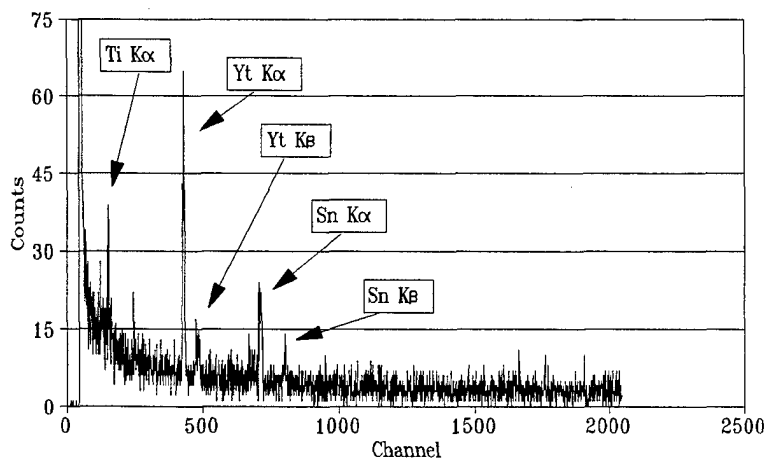
A4. ENERGY CALIBRATION DATA TAKEN 01 DECEMBER 1992

01 Dec 92 Tri-Foil Calibration

01 Dec 92 Tri-Foil Calibration
Gauss1(18.7218, 139.9, 3.05235) Exp2(15.1476, 207.499)
Gauss3(49.2114, 419.753, 3.69376) Gauss4(11.2515, 471.3, 2.39451)
Gauss5(13.2228, 703.79, 5.57356) Gauss6(4.13847, 795.39, 3.61077)
Bkgnd(3.64217) X2=7694.4819 r2=0.78848576

```
                        PeakFit Numerical Summary


Description: 01 Dec 92 Tri-Foil Calibration
X-Y Table Size: 2048    Active Points: 1158
X Variable: Channel
Y Variable: Counts
File Source: CAM12013.PRN


Curve-Fit Std Error= 2.59798875    r2= 0.788485758


Background Coefficients [y=a+bx+cx^2+dx^3]
Background          a          b          c          d
     Order= 0    3.6421668


Curve-Fit Coefficients
Peak#  Type      Ampl       Ctr        Wid1       Wid2       Wid3
  1  Gaussian  18.721774  139.9003   3.0523507
  2  Exp       15.147649  207.49869
  3  Gaussian  49.211393  419.75301  3.6937643
  4  Gaussian  11.251475  471.30001  2.3945063
  5  Gaussian  13.222807  703.79025  5.5735618
  6  Gaussian  4.1384652  795.38972  3.6107706


Measured Values
Peak#  Type      PkAmpl     PkCtr      Wid@HM     Area       %Area
  1  Gaussian  18.721774  139.9003   7.1877174  143.24229  16.119842
  2  Exp       0          0          0          0          0
  3  Gaussian  49.211393  419.75301  8.6981249  455.64305  51.276017
  4  Gaussian  11.251475  471.30001  5.6386007  67.532757  7.5998324
  5  Gaussian  13.222807  703.79025  13.124711  184.73374  20.789103
  6  Gaussian  4.1384652  795.38972  8.5025889  37.456672  4.2152052
     Total                                      888.60851  100


Peak# 1  Gaussian
  PkAmpl       PkCtr        Wid@HM       Area
  18.72177407  139.9002963  7.187717422  143.2422898
  XL @HM       XR @HM       Ctr-XL@HM    Ctr-XR@HM
  136.306436   143.4941534  3.593860322  3.5938571
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  18.72177407  1.374583535   13.61996096   16.02870312  21.41484503
   Ctr  139.9002963  0.257556971   543.1819451   139.3956931  140.4048994
  Wid1  3.052350733  0.261260805   11.68315597   2.540491055  3.564210412


Peak# 2  Exp
  PkAmpl       PkCtr        Wid@HM       Area
  0            0            0            0
  XL @HM       XR @HM       Ctr-XL@HM    Ctr-XR@HM
  0            0            0            0
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  15.14764854  0.711817901   21.28022984   13.75306169  16.54223538
  Rtel  207.4986946  13.84359475   14.98878711   180.3764558  234.6209335


Peak# 3  Gaussian
  PkAmpl       PkCtr        Wid@HM       Area
  49.21139331  419.7530068  8.69812489   455.6430496
  XL @HM       XR @HM       Ctr-XL@HM    Ctr-XR@HM
  415.4039443  424.1020692  4.349062433  4.349062457
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  49.21139331  1.2468732     39.46784108   46.76853122  51.65425539
   Ctr  419.7530068  0.107779398   3894.556983   419.5418464  419.9641671
  Wid1  3.693764321  0.108641542   33.99955723   3.480914848  3.906613794


Peak# 4  Gaussian
  PkAmpl       PkCtr        Wid@HM       Area
  11.25147465  471.3000135  5.638600663  67.5327569
  XL @HM       XR @HM       Ctr-XL@HM    Ctr-XR@HM
  468.4807041  474.1193047  2.819309434  2.819291229
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  11.25147465  1.546681801   7.274589152   8.221230411  14.28171889


                              67
```

```
    Ctr    471.3000135   0.379545559   1241.748196   470.5564115   472.0436156
    Wid1   2.394506304   0.381152137   6.282284878   1.647756672   3.141255935


Peak# 5   Gaussian
    PkAmpl        PkCtr          Wid@HM         Area
    13.22280657   703.7902521    13.12471149    184.7337368
    XL @HM        XR @HM         Ctr-XL@HM      Ctr-XR@HM
    697.2278934   710.3526049    6.56235864     6.562352847
    Parm  Value         Std Error      t-value        95% Confidence Limits
    Ampl  13.22280657   1.014386203    13.0352784     11.23543079   15.21018235
     Ctr  703.7902521   0.492732699    1428.34087     702.8248949   704.7556093
    Wid1  5.5735618     0.495699919    11.2438223     4.602391245   6.544732355


Peak# 6   Gaussian
    PkAmpl        PkCtr          Wid@HM         Area
    4.138465231   795.3897237    8.502588904    37.45667209
    XL @HM        XR @HM         Ctr-XL@HM      Ctr-XR@HM
    791.138434    799.6410229    4.251289686    4.251299218
    Parm  Value         Std Error      t-value        95% Confidence Limits
    Ampl  4.138465231   1.259613796    3.285503257    1.670641891   6.606288571
     Ctr  795.3897237   1.267144324    627.7025502    792.9071466   797.8723008
    Wid1  3.610770623   1.272755518    2.8369711      1.117200146   6.1043411


Background  Order=0    Area=4213.986932
    Parm    Value         Std Error      t-value        95% Confidence Limits
     a      3.642166752   0.138192453    26.35575734    3.371421416   3.912912088


PeakFit Numerical Summary        Aug 20,1993  4:47 PM   Pg. 3

Total Peaks= 6   Coefficient Count= 18   Fitted Count=18
Std Error for Curve= 2.597988749     r2= 0.7884857575
Source    Sum of Squares    DF      Mean Square         F
Regr      28683.598         17      1687.2704           249.983
Error     7694.4819         1140    6.7495455
Total     36378.079         1157


          1 Dec 92 Energy Calibration Linear Regression Calculation

  Element   X-Ray Line  Channel  Energy Kev
  Ti        Kα           139.9    4.507
  Yt        Kα           419.753  14.926
  Yt        Kβ           471.3    16.874
  Sn        Kα           703.79   25.156
  Sn        Kβ           795.39   28.795
            Regression Output:
  Constant                       -0.59206
  Std Err of Y Est                0.136727
  R Squared                       0.999844
  No. of Observations                    5
  Degrees of Freedom                     3

  X Coefficient(s)  0.036843
  Std Err of Coef.  0.000265
```

A5. ENERGY CALIBRATION DATA TAKEN 03 DECEMBER 1992

03 Dec 92 Tri-Foil Calibration

03 Dec 92 Tri-Foil Calibration
Gauss1(3.82108, 195.331, 11.6348) Gauss2(17.5392, 458.023, 8.63661)
Gauss3(4.04428, 507.197, 6.07431) Gauss4(10.723, 735.246, 9.98191)
Gauss5(2.25527, 835.909, 21.912) Exp6(2.3571, 1756.63)
Bkgnd(0.0103326) X2=2630.653 r2=0.72110153
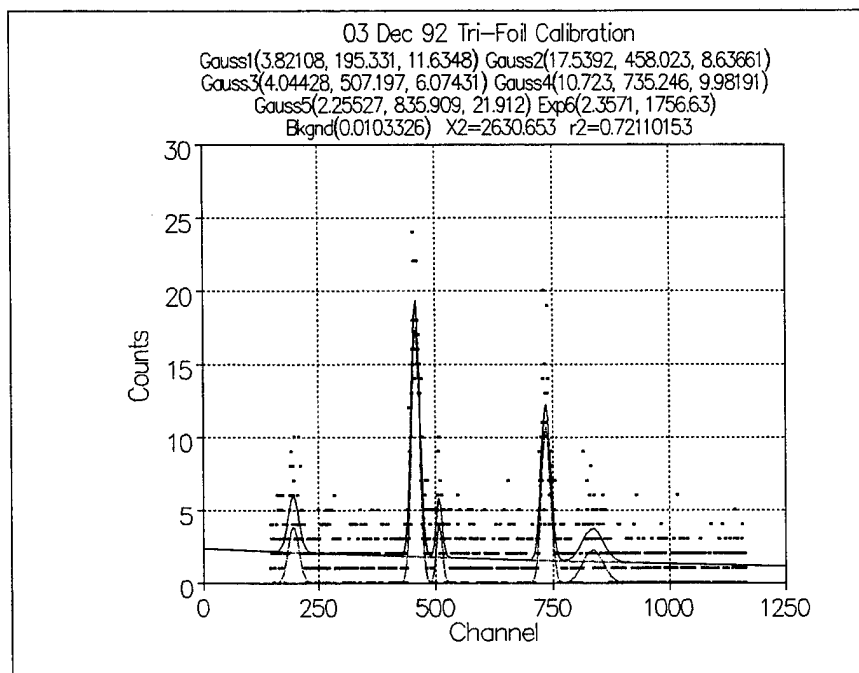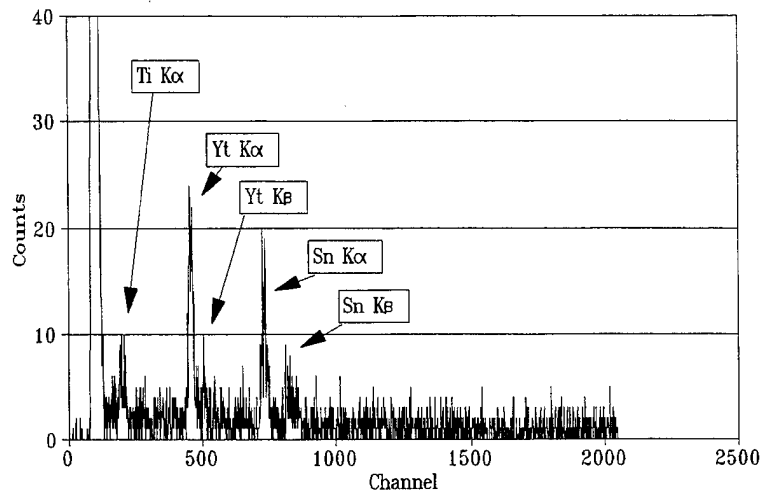
PeakFit Numerical Summary

Description: 03 Dec 92 Tri-Foil Calibration
X-Y Table Size: 2048   Active Points: 1019
X Variable: Channel
Y Variable: Counts
File Source: CM1203X3.PRN

Curve-Fit Std Error= 1.62111844   r2= 0.721101531

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	0.0103326			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	3.8210819	195.33118	11.634837		
2	Gaussian	17.53916	458.02276	8.6366127		
3	Gaussian	4.0442837	507.1969	6.0743102		
4	Gaussian	10.72304	735.24594	9.9819079		
5	Gaussian	2.2552665	835.90881	21.91197		
6	Exp	2.3570975	1756.6334			

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	3.8210819	195.33118	27.39794	111.43798	11.793757
2	Gaussian	17.53916	458.02276	20.337649	379.70197	40.184799
3	Gaussian	4.0442837	507.1969	14.303885	61.578419	6.5169964
4	Gaussian	10.72304	735.24594	23.505543	268.30028	28.394883
5	Gaussian	2.2552665	835.90881	51.598654	123.87091	13.109565
6	Exp	0	0	0	0	0
	Total				944.88955	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
3.821081923	195.3311761	27.39794017	111.4379776
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
181.6322061	209.0301462	13.69896999	13.69897017

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	3.821081923	0.45323636	8.430660596	2.932741401	4.709422446
Ctr	195.3311761	1.540352192	126.8094252	192.3120951	198.350257
Wid1	11.63483738	1.702403024	6.83436132	8.298137758	14.971537

Peak# 2 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
17.53916043	458.022762	20.33764894	379.7019691
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
447.8539319	468.1915809	10.1688201	10.16881884

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	17.53916043	0.511117984	34.31528725	16.53737228	18.54094859
Ctr	458.022762	0.288580493	1587.157735	457.457146	458.5883781
Wid1	8.636612701	0.294618277	29.31458561	8.059162662	9.21406274

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
4.044283718	507.1969001	14.30388541	61.5784185
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
500.0449678	514.3488532	7.151932326	7.151953085

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	4.044283718	0.608480776	6.646526694	2.851665081	5.236902355
Ctr	507.1969001	1.049454407	483.295793	505.1399758	509.2538244
Wid1	6.074310235	1.066614673	5.694943443	3.983751934	8.164868537

```
Peak# 4  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  10.72304008   735.2459361   23.5055432    268.3002811
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  723.4931912   746.9987344   11.75274486   11.75279834
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  10.72304008   0.476811282   22.48906534    9.788492849   11.6575873
  Ctr   735.2459361   0.50742617    1448.971259    734.2513839   736.2404883
  Widl  9.981907941   0.521835567   19.12845458    8.959113388   11.00470249

Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  2.255266526   835.9088083   51.5986544    123.8709064
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  810.1094918   861.7081462   25.79931644   25.79933796
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  2.255266526   0.324475572   6.950497118    1.619296369   2.891236682
  Ctr   835.9088083   3.579650114   233.5169029    828.8927157   842.9249008
  Widl  21.91197013   3.755429229   5.834744525    14.55135158   29.27258869

Peak# 6  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  2.357097497   4.601705509   0.512222586    -6.66221745   11.37641244
  Rtel  1756.633426   5392.278223   0.325768321    -8812.19925   12325.4661

Background  Order=0    Area=10.518574897
  Parm   Value         Std Error     t-value        95% Confidence Limits
  a      0.010332588   4.944983601   0.002089509    -9.68180534   9.702470512

Total Peaks= 6   Coefficient Count= 18   Fitted Count=18
Std Error for Curve= 1.621118439      r2= 0.7211015307
Source   Sum of Squares    DF      Mean Square       F
Regr     6801.6433         17      400.09667         152.242
Error    2630.653          1001    2.628025
Total    9432.2964         1018
```

3 Dec 92 Energy Calibration Linear Regression Calculation

```
Element   X-Ray Line Channel Energy Kev
Ti        Kα            195.331    4.507
Yt        Kα            458.023    14.926
Yt        Kß            507.197    16.874
Sn        Kα            735.246    25.156
Sn        Kß            835.909    28.795
          Regression Output:
Constant                  -2.60226
Std Err of Y Est          0.291635
R Squared                 0.999292
No. of Observations       5
Degrees of Freedom        3

X Coefficient(s)  0.037804
Std Err of Coef.  0.000581
```
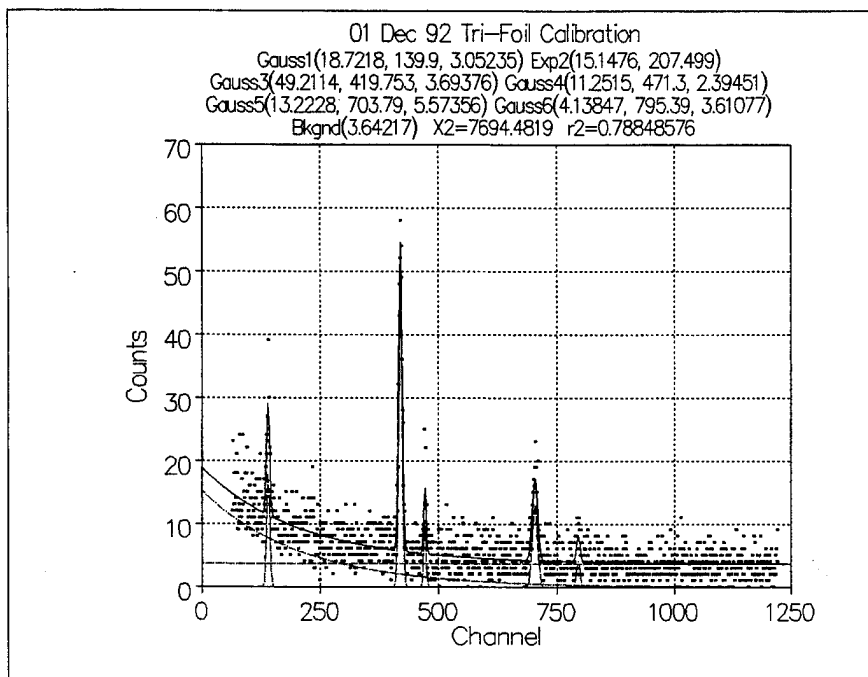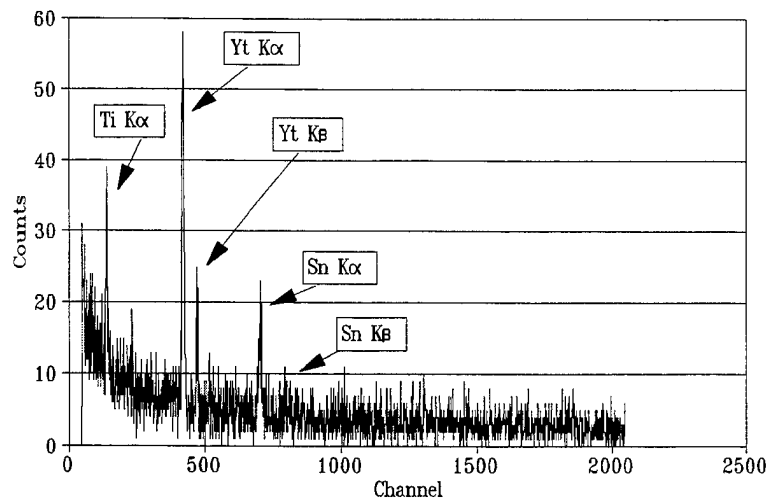
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A6. ENERGY CALIBRATION DATA TAKEN 22 OCTOBER 1992

22 Oct 92 Tri-Foil Calibration

22 Oct 92 Tri-Foil Calibration
Gauss1(44.2911, 126.288, 3.42388)
Gauss2(90.9341, 412.375, 3.86545) Gauss3(15.8536, 462.125, 4.69241)
Exp4(3.43532, 544.768) Gauss5(11.873, 697.32, 5.55122)
Bkgnd(1.53906) X2=5542.3554 r2=0.92770369
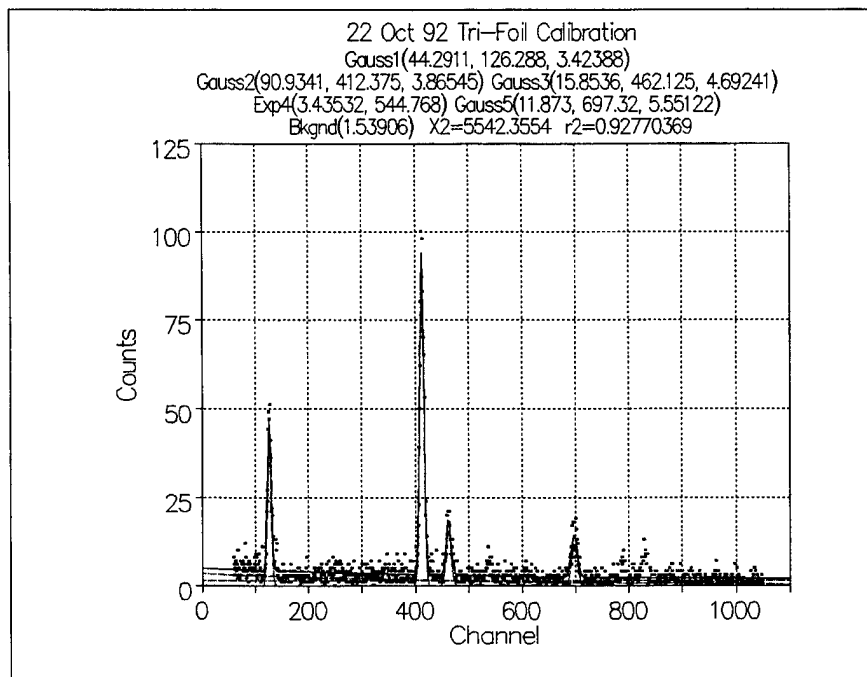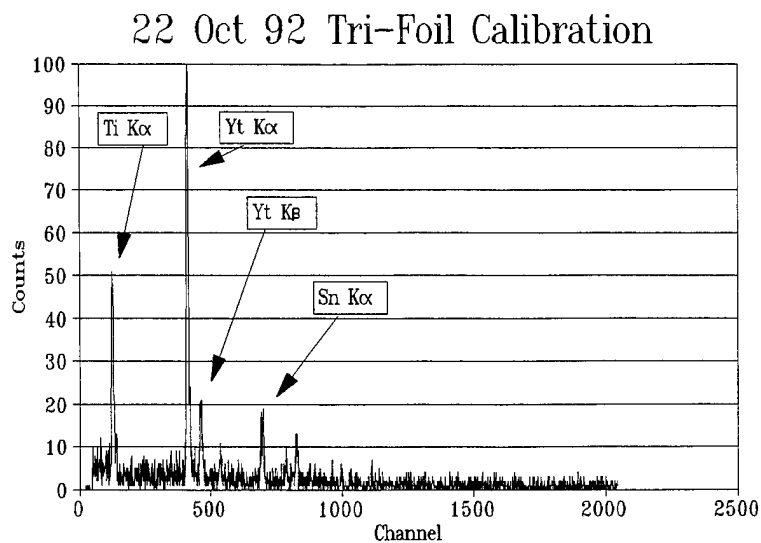
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                        PeakFit Numerical Summary

Description: 22 Oct 92 Tri-Foil Calibration
X-Y Table Size: 2048    Active Points: 991
X Variable: Channel
Y Variable: Counts
File Source: CL1022X1.PRN

Curve-Fit Std Error= 2.38299031    r2= 0.927703694

Background Coefficients [y=a+bx+cx^2+dx^3]
Background          a           b           c           d
     Order= 0    1.5390613

Curve-Fit Coefficients
Peak#  Type      Ampl        Ctr         Wid1        Wid2        Wid3
   1  Gaussian  44.291144   126.28816   3.4238806
   2  Gaussian  90.934061   412.37526   3.865454
   3  Gaussian  15.853636   462.12518   4.6924072
   4  Exp        3.43532    544.76793
   5  Gaussian  11.872979   697.32025   5.5512234

Measured Values
Peak#  Type      PkAmpl      PkCtr       Wid@HM      Area        %Area
   1  Gaussian  44.291144   126.28816   8.0626206   380.12415   23.567907
   2  Gaussian  90.934061   412.37526   9.1024312   881.08155   54.627542
   3  Gaussian  15.853636   462.12518   11.04976    186.47244   11.561394
   4  Exp        0           0           0           0           0
   5  Gaussian  11.872979   697.32025   13.072051   165.21074   10.243157
      Total                                          1612.8889   100

Peak# 1  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  44.29114398  126.2881607   8.06262062    380.1241476
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  122.2568512  130.3194718   4.031309502   4.031311118
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  44.29114398   1.192204975   37.1506116    41.9542474    46.62804057
   Ctr  126.2881607   0.10575926    1194.109726   126.080857    126.4954643
  Wid1  3.423880632   0.107745265   31.77755094   3.212684114   3.635077151

Peak# 2  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  90.93406139  412.3752617   9.102431195   881.0815472
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  407.824047   416.9264782   4.55121473    4.551216465
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  90.93406139   1.11856601    81.29521242   88.74150798   93.1266148
   Ctr  412.3752617   0.054729965   7534.725421   412.267983    412.4825405
  Wid1  3.865454017   0.055250181   69.96273996   3.757155561   3.973752473

Peak# 3  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  15.85363615  462.1251813   11.04975969   186.4724377
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  456.6002978  467.6500575   5.524883487   5.5248762
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  15.85363615   1.015843375   15.60637844   13.86243417   17.84483813
   Ctr  462.1251813   0.345876623   1336.098338   461.4472124   462.8031502
  Wid1  4.692407157   0.34978566    13.415093     4.00677597    5.378038345

Peak# 4  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0            0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0            0             0             0
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  3.435320002   0.492289731   6.978248353   2.470359939   4.400280065
  Rtel  544.7679327   273.040933    1.995187779   9.567664262   1079.968201
```

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```
Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  11.87297866   697.3202483   13.07205135   165.2107449
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  690.7842489   703.8563003   6.535999341   6.53605201
 Parm  Value         Std Error     t-value       95% Confidence Limits
 Ampl  11.87297866   0.93309403    12.72431103   10.04397753   13.7019798
  Ctr  697.3202483   0.502335621   1388.156085   696.3355968   698.3048998
 Widl  5.551223396   0.506613984   10.95750131   4.558185695   6.544261097

Background  Order=0    Area=1523.6706559
  Parm    Value        Std Error     t-value       95% Confidence Limits
   a      1.539061269  0.689794804   2.2311871     0.186962299   2.891160238

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 2.382990306     r2= 0.9277036935
Source    Sum of Squares    DF        Mean Square        F
Regr      71119.312         14        5079.9508          894.571
Error     5542.3554         976       5.6786428
Total     76661.667         990
```

22 Oct 92 Energy Calibration Linear Regression Calculation

```
Element   X-Ray Line Channel Energy Kev
Ti        Kα          126.288    4.507
Yt        Kα          412.375    14.926
Yt        Kβ          462.125    16.874
Sn        Kα          697.32     25.156
          Regression Output:
Constant                      -0.00476
Std Err of Y Est               0.128002
R Squared                      0.999848
No. of Observations            4
Degrees of Freedom             2

X Coefficient(s)  0.036206
Std Err of Coef.  0.000315
```

05 Sep 91 Ti–Cu Calibration

05 Sep 91 Ti–Cu Calibration
Gauss1(30.2381, 235.794, 7.78283)
Gauss2(14.2511, 346.642, 6.20274) Gauss3(8.68968, 365.297, 12.1462)
Exp4(10.2559, 365.605)
Bkgnd(5.32567) X2=6291.0932 r2=0.76876068
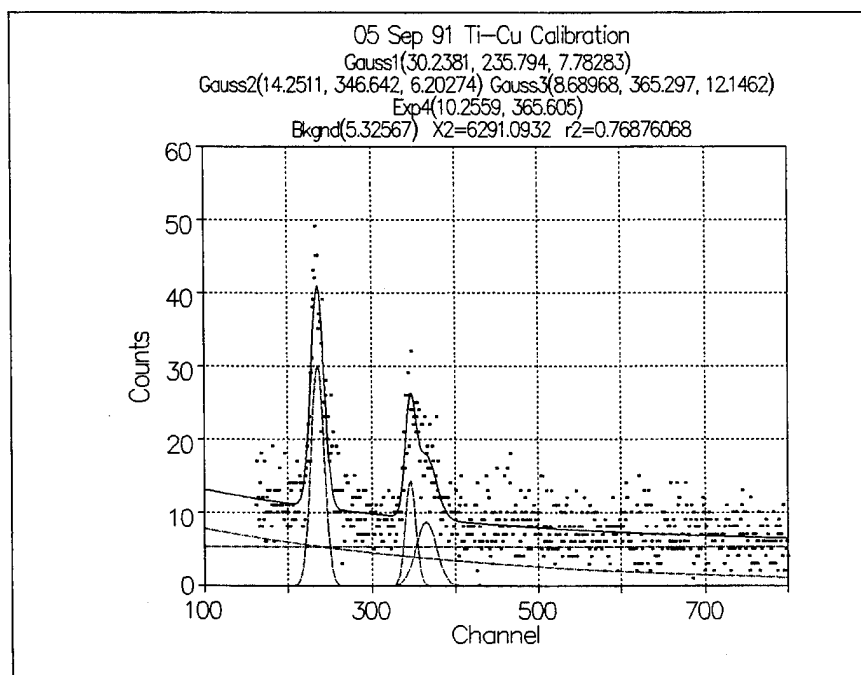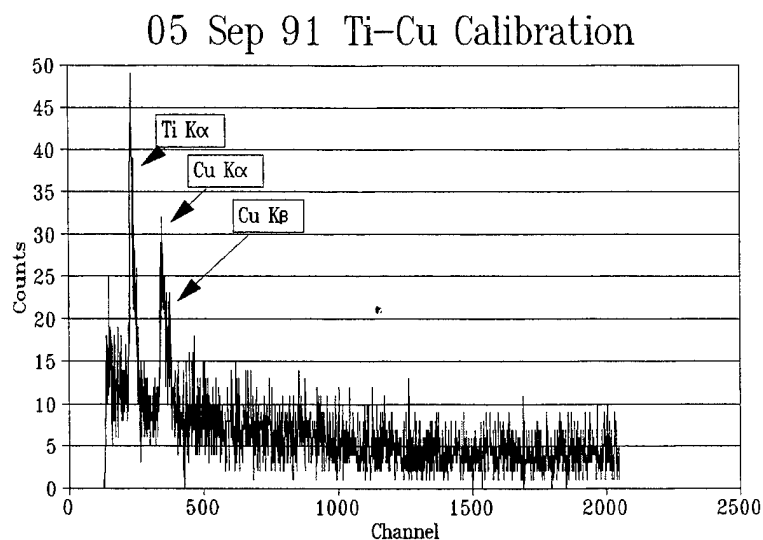
PeakFit Numerical Summary

Description: 05 Sep 91 Ti-Cu Calibration
X-Y Table Size: 2048   Active Points: 639
X Variable: Channel
Y Variable: Counts
File Source: CL905X1.PRN

Curve-Fit Std Error= 3.16759238   r2= 0.768760684

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	5.3256698			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	30.238108	235.794	7.7828328		
2	Gaussian	14.251083	346.64223	6.2027359		
3	Gaussian	8.6896818	365.2966	12.146242		
4	Exp	10.25587	365.60494			

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	30.238108	235.794	18.327154	589.90522	54.821725
2	Gaussian	14.251083	346.64223	14.606299	221.5705	20.591235
3	Gaussian	8.6896818	365.2966	28.602186	264.56707	24.58704
4	Exp	0	0	0	0	0
	Total				1076.0428	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
30.23810849	235.794001	18.32715432	589.905218

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
226.6304318	244.9575861	9.163569163	9.163585153

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	30.23810849	1.061892236	28.47568471	28.15387682	32.32234016
Ctr	235.794001	0.310965137	758.2650694	235.1836534	236.4043486
Wid1	7.782832765	0.325859885	23.88398549	7.143250452	8.422415078

Peak# 2 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
14.25108343	346.6422274	14.60629914	221.570501

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
339.3390739	353.945373	7.303153558	7.303145579

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	14.25108343	3.885374055	3.667879393	6.625055676	21.87711118
Ctr	346.6422274	1.047959489	330.7782707	344.5853423	348.6991126
Wid1	6.202735855	1.179797784	5.257456776	3.88708477	8.518386939

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
8.689681802	365.2966014	28.60218556	264.567072

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
350.9955032	379.5976888	14.30109815	14.30108741

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	8.689681802	1.162693912	7.47374843	6.407601385	10.97176222
Ctr	365.2966014	5.412562492	67.4905097	354.6730806	375.9201221
Wid1	12.14624157	3.994558632	3.040696779	4.305911509	19.98657163

Peak# 4 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	10.2558695	1.053495109	9.735089814	8.188119313	12.32361969
Rtel	365.604939	153.822463	2.376798108	63.68951074	667.5203672

Background Order=0   Area=3397.7773342

```
Parm     Value        Std Error      t-value       95% Confidence Limits
  a    5.325669803   1.276007703   4.17369722    2.821182457   7.830157149

Total Peaks= 4    Coefficient Count= 12    Fitted Count=12
Std Error for Curve= 3.16759238      r2= 0.7687606841
Source    Sum of Squares    DF       Mean Square         F
Regr      20914.891         11       1901.3537           189.498
Error     6291.0932         627      10.033641
Total     27205.984         638
```

05 Sep 91 Energy Calibration Linear Regression Calculations

```
Element   X-Ray Line Channel Energy Kev
Ti        Kα         235.794    4.507
Cu        Kα         346.642    8.037
Cu        Kβ         365.297    8.94
          Regression Output:
Constant                      -3.39068
Std Err of Y Est              0.199691
R Squared                     0.996367
No. of Observations                  3
Degrees of Freedom                   1

X Coefficient(s)  0.033402
Std Err of Coef.  0.002017
```

A8. ENERGY CALIBRATION DATA TAKEN 23 JULY 1991

23 Jul 91 Ti–Cu Calibration

23 Jul 91 Ti–Cu Calibration
Gauss1(43.2977, 207.907, 7.43306)
Gauss2(41.8628, 323.863, 6.82557)
Gauss3(14.2514, 349.392, 7.37195)
Bkgnd(2.58969) X2=3199.714 r2=0.92896707
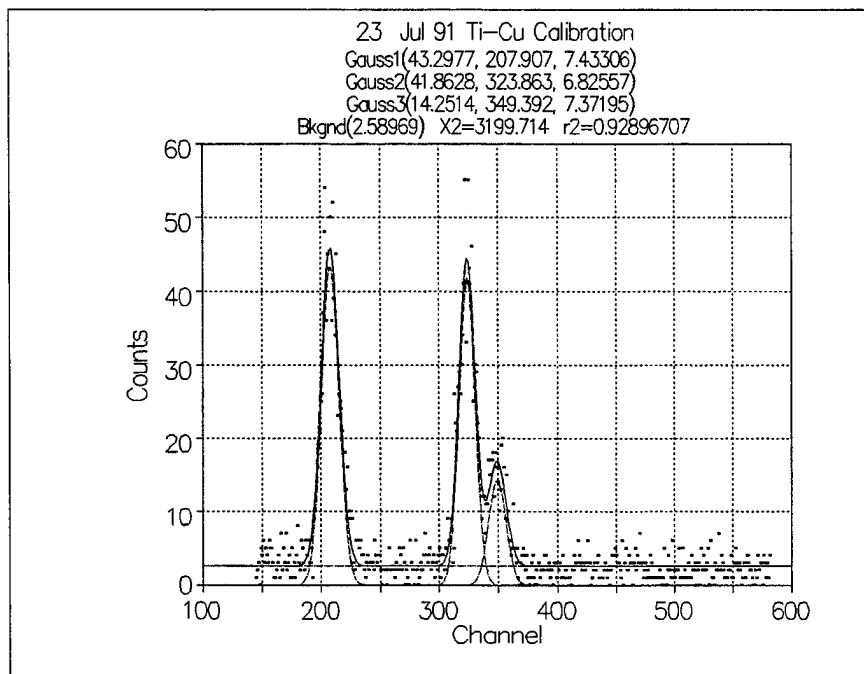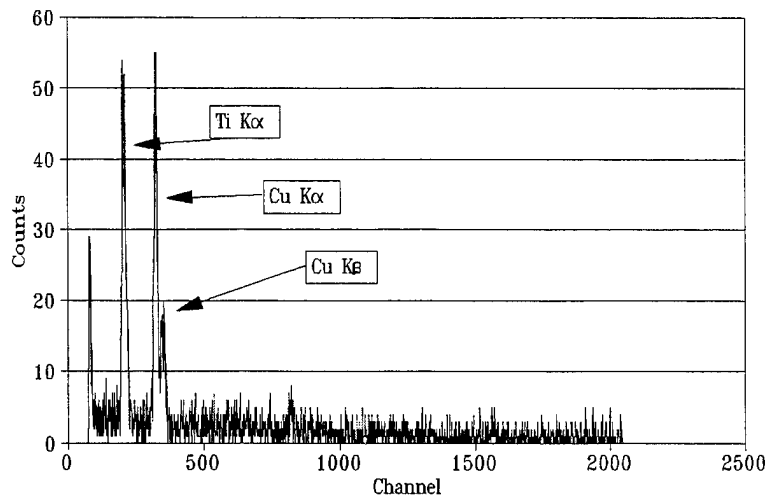
PeakFit Numerical Summary

Description: 23 Jul 91 Ti-Cu Calibration
X-Y Table Size: 2048   Active Points: 437
X Variable: Channel
Y Variable: Counts
File Source: CL723X1.PRN

Curve-Fit Std Error= 2.73742132   r2= 0.928967075

Background Coefficients [y=a+bx+cx^2+dx^3]
Background   a   b   c   d
    Order= 0   2.5896934

Curve-Fit Coefficients
Peak# Type   Ampl   Ctr   Widl   Wid2   Wid3
  1 Gaussian   43.297681 207.90749 7.4330587
  2 Gaussian   41.862844 323.86331 6.8255688
  3 Gaussian   14.251353 349.39218 7.3719492

Measured Values
Peak# Type   PkAmpl   PkCtr   Wid@HM   Area   %Area
  1 Gaussian   43.297681 207.90749 17.503506 806.72011 45.161377
  2 Gaussian   41.862844 323.86331 16.072958 716.23827 40.096071
  3 Gaussian   14.251353 349.39218 17.359569 263.34701 14.742552
     Total   1786.3054 100
Peak# 1 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  43.29768119 207.9074947 17.50350623 806.7201125
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  199.1557407 216.6592469 8.751753959 8.751752272
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 43.29768119   0.9296827   46.57253621   41.47068319 45.12467919
  Ctr   207.9074947   0.183099989   1135.486112   207.5476694 208.2673199
  Widl 7.433058709   0.186653889   39.82268339   7.066249386 7.799868031

Peak# 2 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  41.86284426 323.8633121 16.07295768 716.2382678
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  315.8268211 331.8997788 8.036490964 8.036466714
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 41.86284426   0.983521115   42.56425572   39.93004384 43.79564468
  Ctr   323.8633121   0.206456203   1568.678037   323.4575875 324.2690366
  Widl 6.825568808   0.219760444   31.05913275   6.393698996 7.257438619

Peak# 3 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  14.25135341 349.3921826 17.35956898 263.3470052
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  340.7123956 358.0719645 8.679787021 8.67978196
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 14.25135341   0.95301302   14.95399655   12.37850703 16.12419979
  Ctr   349.3921826   0.626970284   557.2707216   348.1600703 350.6242948
  Widl 7.371949237   0.67856483   10.86403083   6.038444173 8.705454301

Background Order=0   Area=1129.1063244
  Parm   Value   Std Error   t-value   95% Confidence Limits
  a   2.589693405   0.14931073   17.3443222   2.296270278 2.883116532

Total Peaks= 3   Coefficient Count= 10   Fitted Count=10
Std Error for Curve= 2.737421321   r2= 0.9289670749
Source   Sum of Squares   DF   Mean Square   F
Regr   41845.792   9   4649.5324   620.477
Error   3199.714   427   7.4934755
Total   45045.506   436

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23 Jul 91 Energy Calibration Linear Regression Calculations

```
Element   X-Ray Line   Channel  Energy Kev
Ti        Kα           207.907   4.507
Cu        Kα           323.863   8.037
Cu        Kß           349.392   8.94
          Regression Output:
Constant                        -1.96122
Std Err of Y Est                 0.078996
R Squared                        0.999431
No. of Observations                     3
Degrees of Freedom                      1

X Coefficient(s)  0.031059
Std Err of Coef.  0.000741
```

APPENDIX B. CHANNEL CONVERSION PROGRAM

The following Q-Basic program was used to convert data files taken at 8000

channel resolution to 2000 channel resolution.

```
REM QBASIC PROGRAM TO CONVERT 8K CHANNEL FILES TO 2K CHANNEL FILES
REM BY LT JOE THIEN
CLS
INPUT "File name to convert"; INFILE$
INPUT "Save as filename"; OUTFILE$
REM OPEN FILES
OPEN INFILE$ FOR INPUT AS #1
OPEN OUTFILE$ FOR OUTPUT AS #2
REM VAR LIST
REM ICHNL   - INPUT CHNL#
REM ICNTS&  - INPUT COUNTS
REM IROI    - INPUT ROI
REM OCHNL   - OUTPUT CHNL#
REM OCOUNTS- OUTPUT COUNTS
REM READS AND INPUTS START OF FILE
INPUT "Number of lines"; Z
FOR Y = 1 TO Z
LINE INPUT #1, LINE$
WRITE #2, LINE$
NEXT Y
REM READS 4 RECORDS, CONVERTS TO 1
OCHNL = 0
DO
COUNTS& = 0
FOR X = 1 TO 4
INPUT #1, ICHNL, ICNTS&, IROI
COUNTS& = COUNTS& + ICNTS&
IF EOF(1) = -1 THEN EXIT FOR
NEXT X
WRITE #2, OCHNL, COUNTS&
OCHNL = OCHNL + 1
IF EOF(1) = -1 THEN EXIT DO
LOOP
REM CLOSE FILES
CLOSE
END
```

APPENDIX C. UNCORRECTED PXR DATA

This appendix contains the uncorrected PXR spectrums and the Peakfit graphical and numerical analysis of the spectrums.

Section	Date	Beam Energy	Target
C1	25 Sep 92	96 MeV	1.75mm Si
C2	29-30 Sep 92	96 MeV	1.75mm Si
C3	02 Dec 92	91 MeV	1.75mm Si
C4	01 Dec 92	92 MeV	1mm LiF
C5	03 Dec 92	62 MeV	1mm LiF
C6	22 Oct 92	95 MeV	1mm LiF
C7	05 Sep 91	85 MeV	320μm Si
C8	05 Sep 91	85 MeV	44μm Si
C9	23 Jul 91	85 MeV	20μm Si

Table 12. Uncorrected PXR Data Runs.

Sections C7, C8 and C9 are reanalysis of PXR spectrums reported on in Reference 5.

C1. UNCORRECTED SILICON DATA TAKEN 25 SEPTEMBER 1992
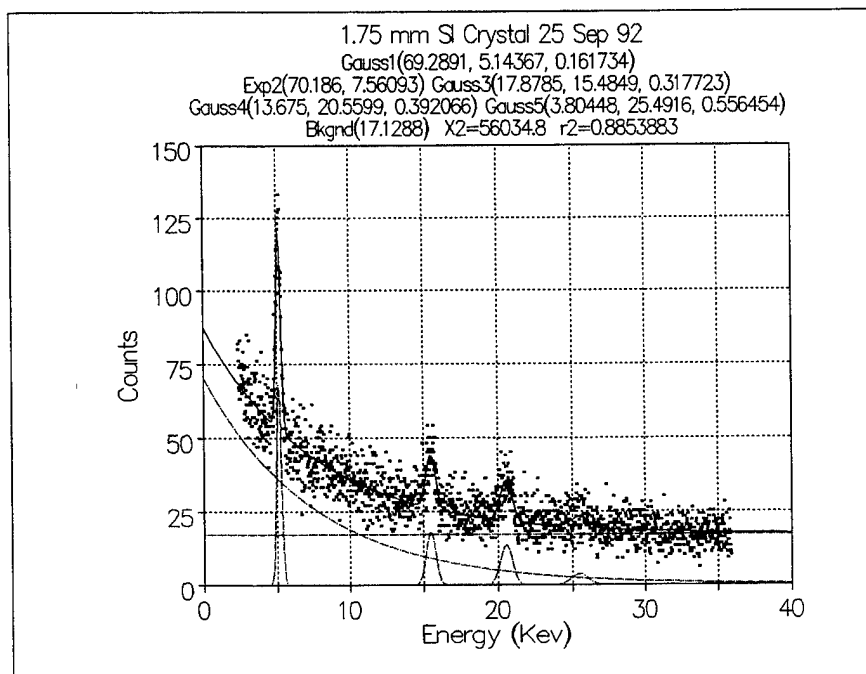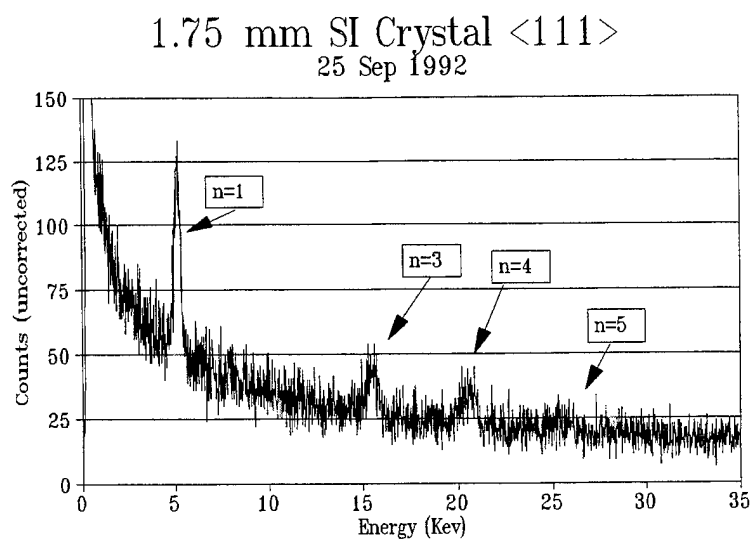
1.75 mm SI Crystal <111>
25 Sep 1992

1.75 mm SI Crystal 25 Sep 92
Gauss1(69.2891, 5.14367, 0.161734)
Exp2(70.186, 7.56093) Gauss3(17.8785, 15.4849, 0.317723)
Gauss4(13.675, 20.5599, 0.392066) Gauss5(3.80448, 25.4916, 0.556454)
Bkgnd(17.1288) X2=56034.8 r2=0.8853883

PeakFit Numerical Summary

Description: 1.75 mm SI Crystal 25 Sep 92
X-Y Table Size: 2048   Active Points: 1775
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI925X04.PRN

Curve-Fit Std Error= 5.64251315   r2= 0.885388299

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	17.128839			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	69.289085	5.1436685	0.1617336		
2	Exp	70.185997	7.5609279			
3	Gaussian	17.878502	15.484855	0.3177234		
4	Gaussian	13.675019	20.559929	0.3920663		
5	Gaussian	3.8044822	25.491575	0.5564538		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	69.289085	5.1436685	0.3808533	28.090213	45.993144
2	Exp	0	0	0	0	0
3	Gaussian	17.878502	15.484855	0.7481803	14.238682	23.313521
4	Gaussian	13.675019	20.559929	0.9232448	13.439321	22.004697
5	Gaussian	3.8044822	25.491575	1.3103463	5.306567	8.6886382
	Total				61.074784	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
69.28908454	5.143668486	0.380853329	28.09021295

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.953241873	5.334095202	0.190426613	0.190426716

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	69.28908454	1.785994497	38.79579956	65.79545013	72.78271894
Ctr	5.143668486	0.004780212	1076.033504	5.134317778	5.153019194
Wid1	0.161733562	0.004883798	33.11634693	0.152180226	0.171286898

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	70.18599676	1.181284709	59.41497102	67.8752523	72.49674123
Rte1	7.560927878	0.203922893	37.07738638	7.162028535	7.959827222

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
17.87850231	15.48485504	0.74818031	14.23868246

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.11076439	15.8589447	0.374090646	0.374089664

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	17.87850231	1.273999755	14.03336401	15.38639532	20.3706093
Ctr	15.48485504	0.025960459	596.4784727	15.43407305	15.53563703
Wid1	0.317723383	0.026506607	11.98657308	0.265873059	0.369573708

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
13.67501875	20.55992924	0.92324478	13.4393212

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
20.09830648	21.02155126	0.461622763	0.461622018

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	13.67501875	1.145856347	11.93432212	11.43357671	15.91646079
Ctr	20.55992924	0.037705104	545.2823842	20.48617322	20.63368526
Wid1	0.392066311	0.038399389	10.21022263	0.316952179	0.467180444

```
Peak# 5  Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  3.804482152    25.49157521    1.310346262    5.306566959
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  24.83640287    26.14674913    0.655172345    0.655173917
 Parm  Value          Std Error      t-value         95% Confidence Limits
 Ampl  3.804482152    0.965946217    3.938606608    1.91496741    5.693996895
  Ctr  25.49157521    0.161479801    157.8623155    25.1757       25.80745042
 Widl  0.556453797    0.166461166    3.342844515    0.230834397   0.882073198

Background  Order=0    Area=573.3639917
  Parm    Value          Std Error      t-value       95% Confidence Limits
   a      17.12883852    0.318250714    53.82183847   16.50629928   17.75137775

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 5.64251315      r2= 0.8853882992
Source    Sum of Squares    DF      Mean Square        F
Regr      432875.14         14      30919.653          971.157
Error     56034.8           1760    31.837955
Total     488909.94         1774
```

1.75 mm Si Crystal <111> (Sn Backing)
29 – 30 Sep 1992

1.75 mm Sl Crystal 29–30 Sep 92
Gauss1(123.095, 5.09348, 0.223985)
Exp2(167.673, 8.56764) Gauss3(42.1179, 15.3575, 0.291137)
Gauss4(32.4716, 20.3976, 0.411602) Gauss5(8.54736, 25.2773, 0.542249)
Bkgnd(49.5628) X2=188344.87 r2=0.93352026

87
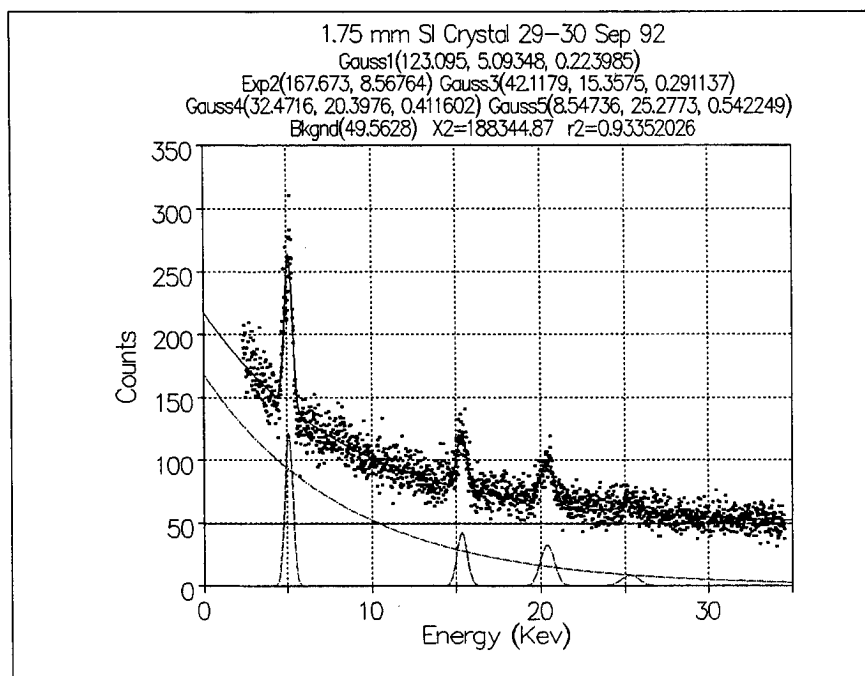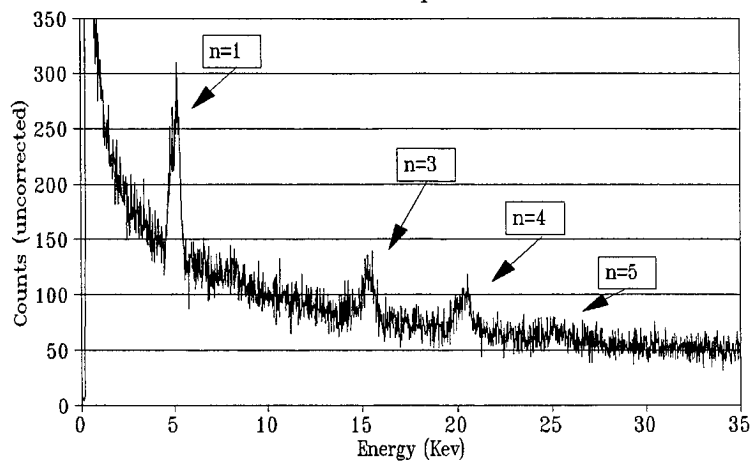
PeakFit Numerical Summary

Description: 1.75 mm SI Crystal 29-30 Sep 92
X-Y Table Size: 2048   Active Points: 1791
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI930X13.PRN

Curve-Fit Std Error= 10.29806   r2= 0.93352026

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	49.562824			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	123.09458	5.0934798	0.2239853		
2	Exp	167.67315	8.5676361			
3	Gaussian	42.117852	15.357468	0.2911374		
4	Gaussian	32.471577	20.397633	0.4116021		
5	Gaussian	8.547362	25.277285	0.5422488		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	123.09458	5.0934798	0.5274446	69.111174	47.673614
2	Exp	0	0	0	0	0
3	Gaussian	42.117852	15.357468	0.6855745	30.736466	21.202337
4	Gaussian	32.471577	20.397633	0.9692467	33.502017	23.110043
5	Gaussian	8.547362	25.277285	1.2768967	11.617692	8.0140058
	Total				144.96735	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
123.094581	5.0934798	0.527444615	69.11117386

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.829757501	5.357202116	0.263722298	0.263722316

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	123.094581	2.712163459	45.38612175	117.7894382	128.3997237
Ctr	5.0934798	0.005641453	902.8666291	5.082444803	5.104514796
Wid1	0.223985252	0.005822164	38.47113627	0.212596776	0.235373728

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	167.6731534	1.87937356	89.21757596	163.9969941	171.3493127
Rtel	8.567636076	0.181182652	47.28728717	8.213232723	8.922039429

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
42.11785188	15.35746838	0.685574503	30.73646567

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.01468102	15.70025553	0.342787355	0.342787148

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	42.11785188	2.369855818	17.77232672	37.48228197	46.75342179
Ctr	15.35746838	0.018783992	817.5827876	15.32072585	15.39421091
Wid1	0.291137382	0.019176836	15.18172161	0.253626424	0.32864834

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
32.47157732	20.39763302	0.969246728	33.50201693

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
19.91300908	20.88225581	0.484623932	0.484622796

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	32.47157732	1.993301778	16.29034684	28.57256807	36.37058656
Ctr	20.39763302	0.028973919	703.9998031	20.34095842	20.45430761
Wid1	0.41160211	0.029585164	13.91244974	0.353731882	0.469472339

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```
Peak# 5  Gaussian
   PkAmpl        PkCtr         Wid@HM        Area
   8.547361993  25.27728453   1.276896658   11.61769169
   XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
   24.63883571  25.91573237   0.638448822   0.638447835
  Parm  Value        Std Error      t-value         95% Confidence Limits
  Ampl  8.547361993  1.743721238    4.901793822    5.136546177   11.95817781
   Ctr  25.27728453  0.12635793     200.0450986    25.03012139   25.52444768
  Widl  0.542248768  0.130514054    4.154715545    0.286956013   0.797541522

Background  Order=0    Area=1593.631644
  Parm    Value        Std Error     t-value       95% Confidence Limits
    a     49.56282402  0.702083116   70.59395517   48.18951036   50.93613768


Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 10.29805997      r2= 0.9335202603
Source    Sum of Squares     DF      Mean Square        F
Regr      2644772            14       188912.28          1781.35
Error     188344.87          1776     106.05004
Total     2833116.8          1790
```

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C3. UNCORRECTED SILICON DATA TAKEN 02 DECEMBER 1992

1.75 mm Si Crystal <111>
02 Dec 1992

1.75 mm SI Crystal 2 Dec 92
Gauss1(145.563, 5.42659, 0.174266) Exp2(77.7444, 7.57327)
Gauss3(43.2551, 15.7563, 0.298337) Gauss4(34.4778, 21.0225, 0.397313)
Gauss5(8.85371, 26.3335, 0.693125) Gauss6(5.10682, 41.8695, 0.0456615)
Bkgnd(16.4334) X2=46131.708 r2=0.92071486
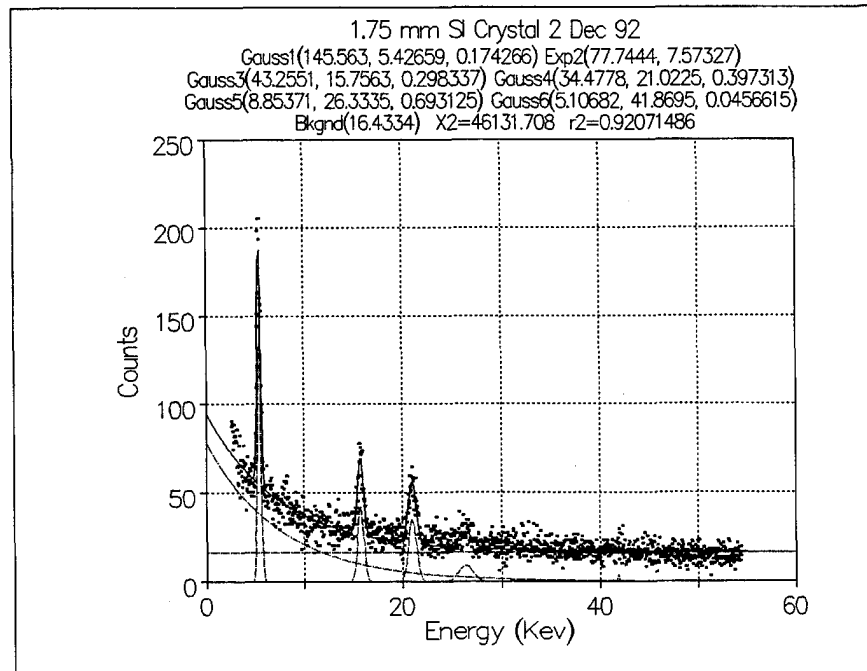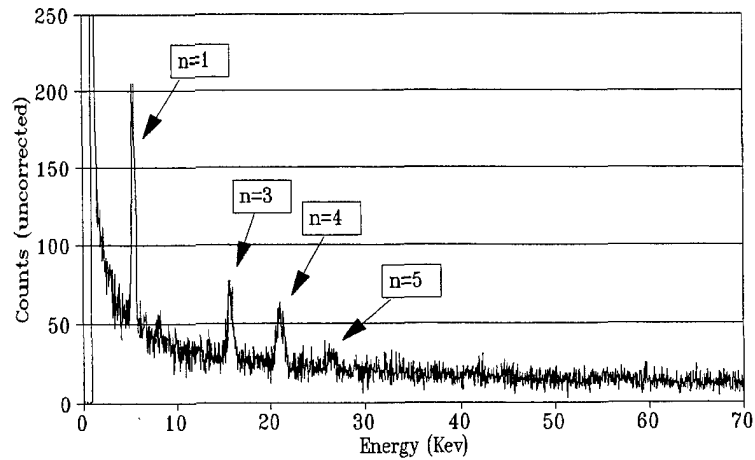
PeakFit Numerical Summary

Description: 1.75 mm SI Crystal 2 Dec 92
X-Y Table Size: 2048   Active Points: 1396
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI1202Y2.PRN

Curve-Fit Std Error= 5.78595643   r2= 0.920714858

Background Coefficients [y=a+bx+cx^2+dx^3]
Background   a   b   c   d
    Order= 0   16.433363

Curve-Fit Coefficients
Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	145.56285	5.426595	0.1742659		
2	Exp	77.744373	7.5732685			
3	Gaussian	43.255097	15.756303	0.2983369		
4	Gaussian	34.47776	21.02249	0.3973126		
5	Gaussian	8.8537085	26.333534	0.6931246		
6	Gaussian	5.1068174	41.869497	0.0456615		

Measured Values
Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	145.56285	5.426595	0.4103644	63.584731	43.481004
2	Exp	0	0	0	0	0
3	Gaussian	43.255097	15.756303	0.7025279	32.34701	22.119783
4	Gaussian	34.47776	21.02249	0.9355975	34.336921	23.48054
5	Gaussian	8.8537085	26.333534	1.6321822	15.382483	10.518969
6	Gaussian	5.1068174	41.869497	0.1075225	0.5845097	0.399704
	Total				146.23566	100

Peak# 1 Gaussian
PkAmpl	PkCtr	Wid@HM	Area
145.5628498	5.426594993	0.410364367	63.58473089

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
5.221412762	5.631777129	0.205182231	0.205182136

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	145.5628498	2.474366859	58.8283218	140.7181839	150.4075158
Ctr	5.426594993	0.003395483	1598.18039	5.419946834	5.433243151
Wid1	0.174265864	0.003472925	50.17841693	0.16746608	0.181065648

Peak# 2 Exp
PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	77.74437278	1.759237634	44.19208144	74.29988813	81.18885743
Rtel	7.573268508	0.21460257	35.28973811	7.153089195	7.993447821

Peak# 3 Gaussian
PkAmpl	PkCtr	Wid@HM	Area
43.25509678	15.75630278	0.702527943	32.34700976

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.40503887	16.10756681	0.351263912	0.351264031

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	43.25509678	1.889029181	22.89805643	39.55648785	46.95370571
Ctr	15.75630278	0.014946355	1054.190311	15.72703869	15.78556687
Wid1	0.298336869	0.015238616	19.57768812	0.268500548	0.328173189

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```
Peak# 4   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  34.47776004    21.02249016    0.935597543    34.33692129
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  20.55469095    21.49028849    0.467799211    0.467798332
  Parm  Value         Std Error      t-value        95% Confidence Limits
  Ampl  34.47776004   1.634364023    21.09552067    31.27777063   37.67774945
  Ctr   21.02249016   0.021640471    971.4432743    20.98011938   21.06486094
  Widl  0.397312632   0.021964       18.08926593    0.354308402   0.440316862

Peak# 5   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  8.853708454    26.333534      1.632182218    15.38248342
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  25.51744316    27.14962538    0.81609084     0.816091378
  Parm  Value         Std Error      t-value        95% Confidence Limits
  Ampl  8.853708454   1.238674852    7.147726005    6.428455358   11.27896155
  Ctr   26.333534     0.111327023    236.5421552    26.11556218   26.55150582
  Widl  0.693124607   0.113315195    6.116784329    0.471260067   0.914989147

Peak# 6   Gaussian
  PkAmpl         PkCtr          Wid@HM         Area
  5.106817443    41.86949672    0.107522452    0.584509726
  XL @HM         XR @HM         Ctr-XL@HM      Ctr-XR@HM
  41.815735      41.92325745    0.053761723    0.053760729
  Parm  Value         Std Error      t-value        95% Confidence Limits
  Ampl  5.106817443   4.79920509     1.064096522    -4.28974614   14.50338102
  Ctr   41.86949672   0.049525618    845.4108959    41.77252845   41.96646499
  Widl  0.045661489   0.049598458    0.920623161    -0.0514494    0.142772376

Background  Order=0     Area=850.15662478
  Parm   Value         Std Error      t-value        95% Confidence Limits
   a     16.43336315   0.244136373    67.3122279     15.95535837   16.91136792

Total Peaks= 6   Coefficient Count= 18   Fitted Count=18
Std Error for Curve= 5.78595643        r2= 0.9207148577
Source    Sum of Squares     DF       Mean Square           F
Regr      535713.85          17       31512.58              941.312
Error     46131.708          1378     33.477292
Total     581845.56          1395
```

C4. UNCORRECTED LITHIUM FLUORIDE DATA TAKEN 01 DECEMBER 1992

1 mm LiF Crystal <220>
1 Dec 1992

1 mm LiF Crystal 1 Dec 92
Gauss1(233.496, 11.4261, 0.238101)
Gauss2(26.91, 23.0219, 0.401947) Gauss3(−9.47869, 40.4451, 0.341151)
Exp4(50.867, 42.9472)
Bkgnd(−2.84182) X2=43790.061 r2=0.95212346
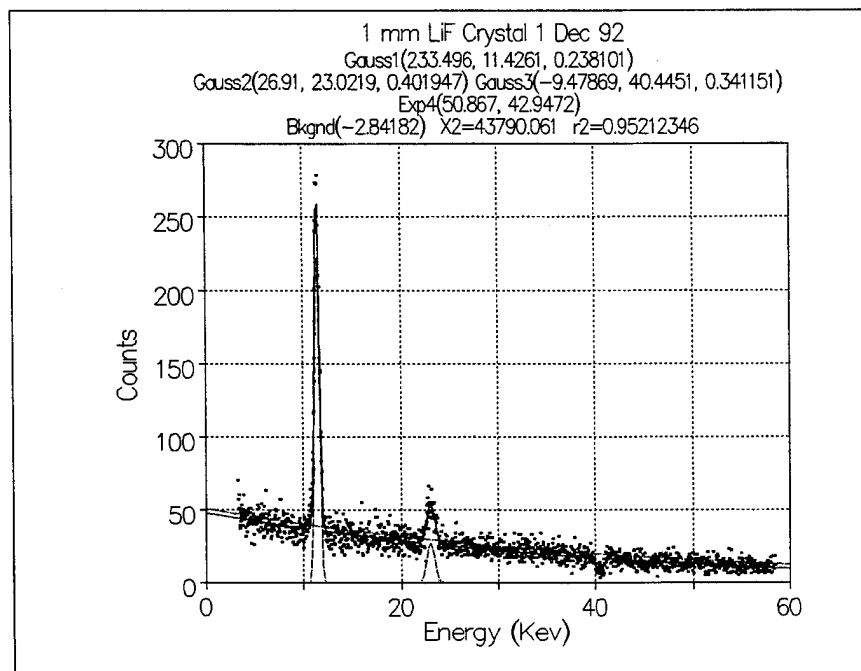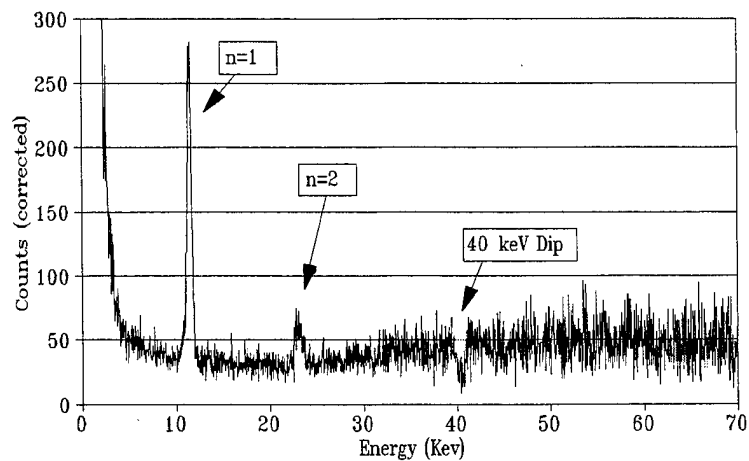
PeakFit Numerical Summary

Description: 1 mm LiF Crystal 1 Dec 92
X-Y Table Size: 2048   Active Points: 1498
X Variable: Energy (Kev)
Y Variable: Counts
File Source: LI1201Y1.PRN

Curve-Fit Std Error= 5.4284816   r2= 0.952123457

Background Coefficients [y=a+bx+cx^2+dx^3]
Background   a   b   c   d
    Order= 0   -2.841825

Curve-Fit Coefficients
Peak# Type   Ampl   Ctr   Wid1   Wid2   Wid3
  1 Gaussian   233.49555   11.426061   0.2381008
  2 Gaussian   26.909961 23.021917   0.4019469
  3 Gaussian   -9.47869   40.445122   0.3411507
  4 Exp   50.866994 42.94722

Measured Values
Peak# Type   PkAmpl   PkCtr   Wid@HM   Area   %Area
  1 Gaussian   233.49555   11.426061   0.5606838   139.3572   87.997893
  2 Gaussian   26.909961 23.021917   0.9465112   27.112637   17.120428
  3 Gaussian   -9.47869   40.445122   0.8033495   -8.10559   -5.11832
  4 Exp   0   0   0   0   0
       Total   158.36425   100

Peak# 1 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  233.4955514   11.42606142   0.560683799   139.3572032
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  11.14571978   11.70640358   0.280341639   0.28034216
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 233.4955514   1.971721065   118.4222026   229.6360836   237.3550192
   Ctr 11.42606142   0.002313156   4939.598856   11.42153362   11.43058922
  Wid1 0.238100811   0.002338781   101.8055192   0.233522856   0.242678766

Peak# 2 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  26.90996134   23.02191677   0.946511158   27.11263692
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  22.54866172   23.49517288   0.473255048   0.47325611
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 26.90996134   1.520472299   17.69842263   23.9337727   29.88614999
   Ctr 23.02191677   0.026077538   882.8255452   22.97087232   23.07296122
  Wid1 0.401946949   0.026513962   15.15982217   0.350048238   0.45384566

Peak# 3 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  -9.47869001   40.44512226   0.803349497   -8.10558974
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  40.04344737   40.84679686   0.401674898   0.401674599
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl -9.47869001   1.646389334   -5.75725912   -12.70135   -6.25603002
   Ctr 40.44512226   0.068205953   592.985219   40.3116152   40.57862932
  Wid1 0.341150747   0.068857413   4.954451984   0.206368514   0.475932979

Peak# 4 Exp
  PkAmpl   PkCtr   Wid@HM   Area
  0   0   0   0
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  0   0   0   0
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 50.86699418   1.991728576   25.53911953   46.96836348   54.76562488
  Rte1 42.94721964   3.992538856   10.75686955   35.13218162   50.76225766

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```
Background  Order=0     Area=-156.73790888
 Parm     Value          Std Error      t-value        95% Confidence Limits
  a     -2.84182455   2.431695144   -1.16865988   -7.60165049  1.918001386


Total Peaks= 4   Coefficient Count= 12   Fitted Count=12
Std Error for Curve= 5.428481597      r2= 0.9521234568
Source    Sum of Squares      DF       Mean Square        F
Regr      870855.36           11       79168.669          2686.56
Error     43790.061           1486     29.468412
Total     914645.42           1497
```

1 mm LiF Crystal <220>
3 Dec 1992 (60 Mev Beam)

1 mm LiF Crystal 3 Dec 92 (60 Mev)
Gauss1(59.1698, 11.2811, 0.337859)
Exp2(28.3213, 18.3919) Gauss3(2.36409, 23.4118, 0.76646)
Gauss4(−1.2393, 37.2372, 0.461112)
Bkgnd(6.39269) X2=23566.877 r2=0.85361792

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PeakFit Numerical Summary

Description: 1 mm LiF Crystal 3 Dec 92 (60 Mev)
X-Y Table Size: 2048   Active Points: 1667
X Variable: Energy (Kev)
Y Variable: Counts
File Source: LI1203Y1.PRN

Curve-Fit Std Error= 3.77356661   r2= 0.853617919

Background Coefficients [y=a+bx+cx^2+dx^3]
Background   a   b   c   d
       Order= 0   6.3926869

Curve-Fit Coefficients
Peak# Type   Ampl   Ctr   Wid1   Wid2   Wid3
   1 Gaussian   59.169762 11.281125 0.3378593
   2 Exp   28.321278 18.391933
   3 Gaussian   2.3640929 23.41183   0.7664595
   4 Gaussian   -1.239303 37.237172 0.4611117

Measured Values
Peak# Type   PkAmpl   PkCtr   Wid@HM   Area   %Area
   1 Gaussian   59.169762 11.281125 0.7955972 50.110143 94.157171
   2 Exp   0   0   0   0   0
   3 Gaussian   2.3640929 23.41183   1.804873   4.5419649 8.5343713
   4 Gaussian   -1.239303 37.237172 1.0858393 -1.43243   -2.691542
      Total   53.219678 100

Peak# 1   Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  59.16976176 11.28112538 0.795597168   50.11014312
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  10.88332659 11.67892376 0.397798792   0.397798376
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 59.16976176 1.168113747   50.6541096   56.8842181   61.45530543
   Ctr 11.28112538 0.007657743   1473.165765   11.26614216 11.29610861
  Wid1 0.337859319 0.007792016   43.35968226   0.322613379 0.353105258

Peak# 2   Exp
  PkAmpl   PkCtr   Wid@HM   Area
  0   0   0   0
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  0   0   0   0
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 28.32127825 0.545645665   51.90415699   27.25366219 29.3888943
  Rtel 18.3919328   0.876332229   20.98739746   16.67729193 20.10657367

Peak# 3   Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  2.364092937 23.41183023 1.804872965   4.541964928
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  22.50939428 24.31426724 0.902435952   0.902437014
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 2.364092937 0.780792402   3.027812428   0.8363863   3.891799575
   Ctr 23.41183023 0.288663896   81.10411631   22.84702741 23.97663305
  Wid1 0.766459549 0.299294967   2.560883522   0.180855864 1.352063233

Peak# 4   Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  -1.23930261 37.23717224 1.085839348   -1.43243013
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  36.69425308 37.78009242 0.542919166   0.542920183
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl -1.23930261 0.997901903   -1.24190825   -3.19180798 0.713202768
   Ctr 37.23717224 0.427065181   87.19318254   36.40157201 38.07277247
  Wid1 0.461111693 0.432077956   1.067195599   -0.38429659 1.306519973

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```
Background  Order=0     Area=402.620783
  Parm    Value        Std Error     t-value       95% Confidence Limits
   a    6.39268695    0.293850959  21.75486159  5.817735067  6.967638832

Total Peaks= 4   Coefficient Count= 12   Fitted Count=12
Std Error for Curve= 3.773566612      r2= 0.8536179186
Source    Sum of Squares    DF       Mean Square        F
Regr      137428.77         11       12493.524          877.366
Error      23566.877        1655     14.239805
Total     160995.64         1666
```

C6. UNCORRECTED LITHIUM FLUORIDE DATA TAKEN 22 OCTOBER 1992
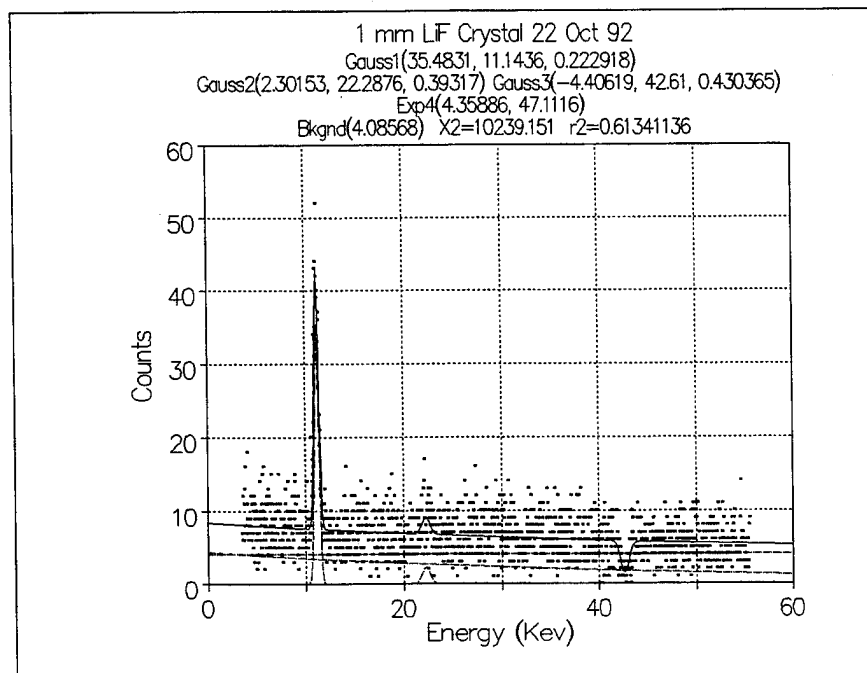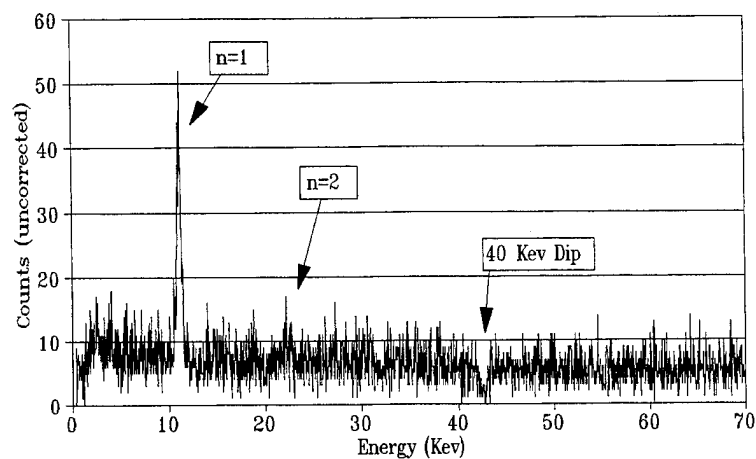
1 mm LiF Crystal <220>
22 Oct 1992

1 mm LiF Crystal 22 Oct 92
Gauss1(35.4831, 11.1436, 0.222918)
Gauss2(2.30153, 22.2876, 0.39317) Gauss3(−4.40619, 42.61, 0.430365)
Exp4(4.35886, 47.1116)
Bkgnd(4.08568) X2=10239.151 r2=0.61341136

```
                        PeakFit Numerical Summary


Description: 1 mm LiF Crystal 22 Oct 92
X-Y Table Size: 2048   Active Points: 1436
X Variable: Energy (Kev)
Y Variable: Counts
File Source: LI1022X1.PRN


Curve-Fit Std Error= 2.68149496      r2= 0.613411356


Background Coefficients [y=a+bx+cx^2+dx^3]
Background          a          b          c          d
      Order= 0   4.0856779


Curve-Fit Coefficients
Peak#  Type        Ampl       Ctr        Widl       Wid2       Wid3
   1  Gaussian    35.483102  11.143649  0.2229178
   2  Gaussian     2.3015343 22.287562  0.3931702
   3  Gaussian    -4.406189  42.610002  0.4303655
   4  Exp          4.3588578 47.111575


Measured Values
Peak#  Type        PkAmpl     PkCtr      Wid@HM     Area       %Area
   1  Gaussian    35.483102  11.143649  0.5249303  19.826939  114.32948
   2  Gaussian     2.3015343 22.287562  0.9258436   2.2682345  13.079481
   3  Gaussian    -4.406189  42.610002  1.0134372  -4.753242  -27.40896
   4  Exp          0          0          0          0          0
      Total                                        17.341931 100


Peak# 1  Gaussian
   PkAmpl        PkCtr        Wid@HM        Area
   35.48310234  11.14364903  0.524930314   19.82693859
   XL @HM        XR @HM       Ctr-XL@HM     Ctr-XR@HM
   10.88118411  11.40611442  0.262464928   0.262465386
   Parm  Value        Std Error     t-value       95% Confidence Limits
   Ampl  35.48310234  0.997856916   35.55930892   33.52958459  37.4366201
   Ctr   11.14364903  0.007212137   1545.124357   11.12952974  11.15776833
   Widl  0.222917816  0.007292225   30.56924425   0.20864173   0.237193903


Peak# 2  Gaussian
   PkAmpl        PkCtr        Wid@HM        Area
   2.301534314  22.28756195  0.925843583   2.268234491
   XL @HM        XR @HM       Ctr-XL@HM     Ctr-XR@HM
   21.82463978  22.75048336  0.462922168   0.462921415
   Parm  Value        Std Error     t-value       95% Confidence Limits
   Ampl  2.301534314  0.752848134   3.057103034   0.827673509  3.77539512
   Ctr   22.28756195  0.147666252   150.9319951   21.99847376  22.57665013
   Widl  0.393170164  0.150159771   2.618345515   0.099200382  0.687139946


Peak# 3  Gaussian
   PkAmpl        PkCtr        Wid@HM        Area
   -4.4061889   42.61000214  1.013437155   -4.75324235
   XL @HM        XR @HM       Ctr-XL@HM     Ctr-XR@HM
   42.10328239  43.11671955  0.506719749   0.506717407
   Parm  Value        Std Error     t-value       95% Confidence Limits
   Ampl  -4.4061889   0.718930303   -6.12881232   -5.81364832  -2.99872948
   Ctr   42.61000214  0.080704127   527.9779838   42.4520066   42.76799768
   Widl  0.430365488  0.08185176    5.257864804   0.270123209  0.590607768


Peak# 4  Exp
   PkAmpl        PkCtr        Wid@HM        Area
   0             0            0             0
   XL @HM        XR @HM       Ctr-XL@HM     Ctr-XR@HM
   0             0            0             0
   Parm  Value        Std Error     t-value       95% Confidence Limits
   Ampl  4.35885776   1.408594619   3.094472818   1.601233338  7.116482182
   Rtel  47.11157452  31.93451055   1.475255882   -15.4070415  109.6301906




                              100
```
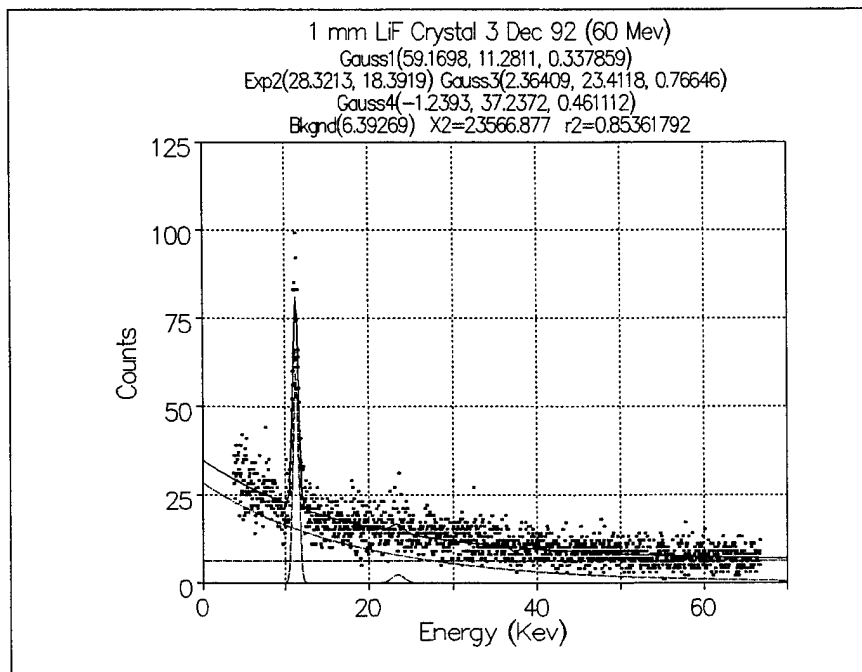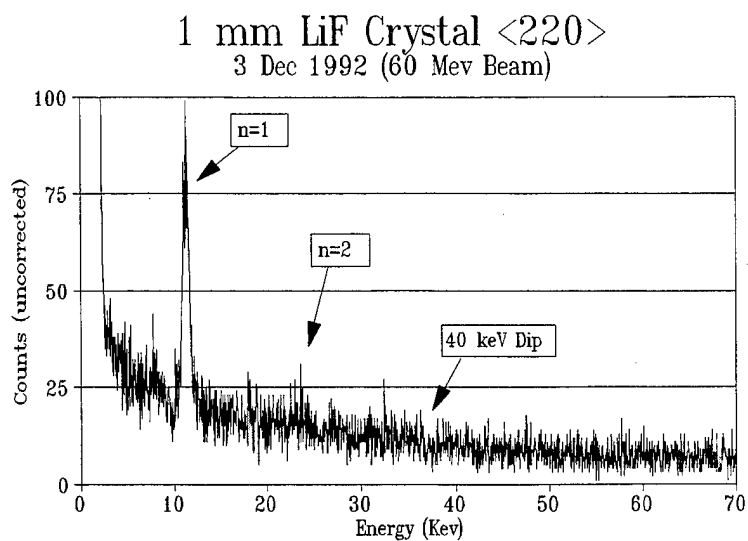
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Background  Order=0     Area=212.2738892
 Parm     Value        Std Error     t-value      95% Confidence Limits
   a    4.085677932   1.647034452   2.480626879   0.861256678  7.310099185


Total Peaks= 4   Coefficient Count= 12   Fitted Count=12
Std Error for Curve= 2.681494961      r2= 0.6134113562
Source   Sum of Squares     DF      Mean Square         F
Regr     16246.757          11      1476.9779           205.409
Error    10239.151          1424    7.1904152
Total    26485.908          1435
```

320 um Si Crystal <111>
5 Sep 1991

320 um Si Crystal 5 Sep 91
Gauss1(182.094, 5.20292, 0.316276)
Gauss2(52.3714, 16.6926, 0.396375) Gauss3(35.1147, 22.4876, 0.407261)
Exp4(38.023, 25.2516) Gauss5(6.2818, 28.2248, 0.41269)
Bkgnd(12.1576) X2=41775.343 r2=0.94797125

102

```
                        PeakFit Numerical Summary

Description: 320 um Si Crystal 5 Sep 91
X-Y Table Size: 2048    Active Points: 1084
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI905T32.PRN

Curve-Fit Std Error= 6.2513118     r2= 0.947971247

Background Coefficients [y=a+bx+cx^2+dx^3]
Background          a           b           c           d
        Order= 0    12.157602

Curve-Fit Coefficients
Peak#  Type        Ampl        Ctr         Wid1        Wid2        Wid3
   1   Gaussian    182.094     5.202924    0.3162762
   2   Gaussian    52.371441   16.692642   0.3963745
   3   Gaussian    35.114699   22.48765    0.4072609
   4   Exp         38.022988   25.251564
   5   Gaussian    6.2818032   28.22476    0.4126904

Measured Values
Peak#  Type        PkAmpl      PkCtr       Wid@HM      Area        %Area
   1   Gaussian    182.094     5.202924    0.7447733   144.362     60.467909
   2   Gaussian    52.371441   16.692642   0.9333896   52.034345   21.795265
   3   Gaussian    35.114699   22.48765    0.9590236   35.846887   15.014937
   4   Exp         0           0           0           0           0
   5   Gaussian    6.2818032   28.22476    0.9718108   6.4982816   2.7218901
       Total                                           238.74152   100

Peak# 1  Gaussian
   PkAmpl          PkCtr           Wid@HM          Area
   182.0940009     5.202924042     0.744773253     144.3620016
   XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
   4.830537339     5.575310592     0.372386703     0.37238655
   Parm  Value           Std Error       t-value         95% Confidence Limits
   Ampl  182.0940009     1.904302369     95.62241996     178.362345      185.8256567
   Ctr   5.202924042     0.003751938     1386.72984      5.195571775     5.21027631
   Wid1  0.316276178     0.003959931     79.86910943     0.308516328     0.324036028

Peak# 2  Gaussian
   PkAmpl          PkCtr           Wid@HM          Area
   52.37144131     16.69264198     0.933389608     52.03434479
   XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
   16.22594727     17.15933688     0.466694708     0.4666949
   Parm  Value           Std Error       t-value         95% Confidence Limits
   Ampl  52.37144131     1.686750444     31.04871945     49.06609851     55.67678412
   Ctr   16.69264198     0.014590911     1144.043864     16.66404975     16.72123421
   Wid1  0.396374507     0.015033304     26.36642724     0.366915364     0.42583365

Peak# 3  Gaussian
   PkAmpl          PkCtr           Wid@HM          Area
   35.1146993      22.48764954     0.959023613     35.8468872
   XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
   22.00813721     22.96716083     0.479512332     0.479511281
   Parm  Value           Std Error       t-value         95% Confidence Limits
   Ampl  35.1146993      1.66200011      21.12797652     31.85785705     38.37154155
   Ctr   22.48764954     0.022058849     1019.438924     22.4444232      22.53087589
   Wid1  0.407260854     0.022649663     17.9808795      0.362876755     0.451644954

Peak# 4  Exp
   PkAmpl          PkCtr           Wid@HM          Area
   0               0               0               0
   XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
   0               0               0               0
   Parm  Value           Std Error       t-value         95% Confidence Limits
   Ampl  38.02298816     2.095543296     18.14469223     33.91657812     42.1293982
   Rte1  25.25156386     4.147520103     6.088352373     17.12411633     33.37901139
```

```
Peak# 5  Gaussian
  PkAmpl          PkCtr          Wid@HM          Area
  6.281803185    28.22475999    0.97181083      6.498281647
  XL @HM          XR @HM         Ctr-XL@HM       Ctr-XR@HM
  27.73885495    28.71066578    0.485905045     0.485905785
 Parm  Value          Std Error      t-value         95% Confidence Limits
 Ampl  6.281803185    1.647658865    3.812562976    3.053063929   9.51054244
  Ctr  28.22475999    0.124141769    227.3590934    27.98149277   28.46802722
 Widl  0.412690383    0.126719299    3.256728749    0.16437225    0.661008517

Background  Order=0     Area=439.79355138
  Parm    Value         Std Error      t-value         95% Confidence Limits
   a     12.15760219   2.853783892    4.260169183    6.565349891   17.74985449


Total Peaks= 5   Coefficient Count= 15    Fitted Count=15
Std Error for Curve= 6.251311796       r2= 0.9479712474
Source    Sum of Squares     DF       Mean Square          F
Regr      761152.67          14       54368.048            1391.24
Error     41775.343          1069     39.078899
Total     802928.02          1083
```
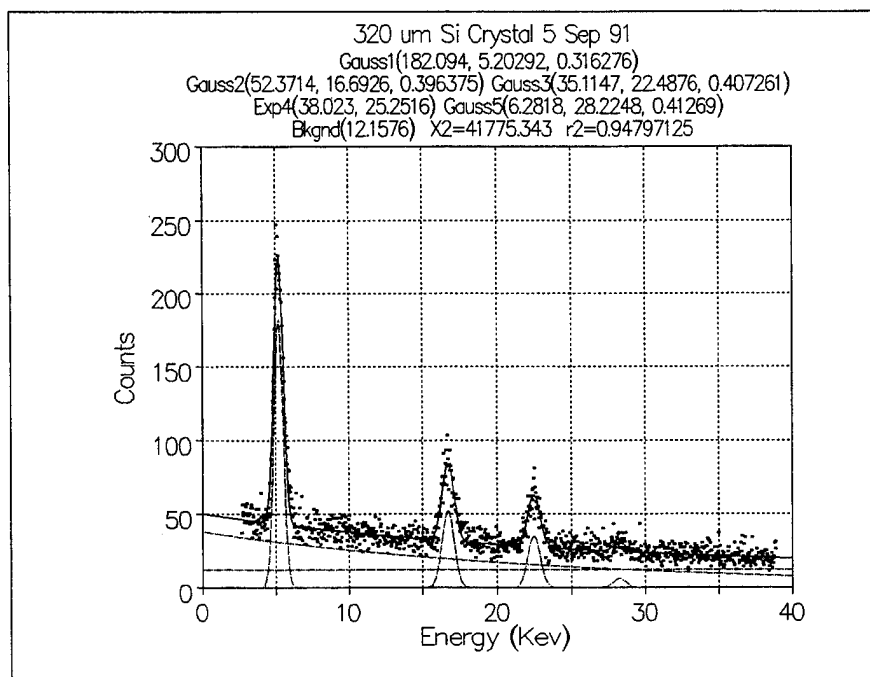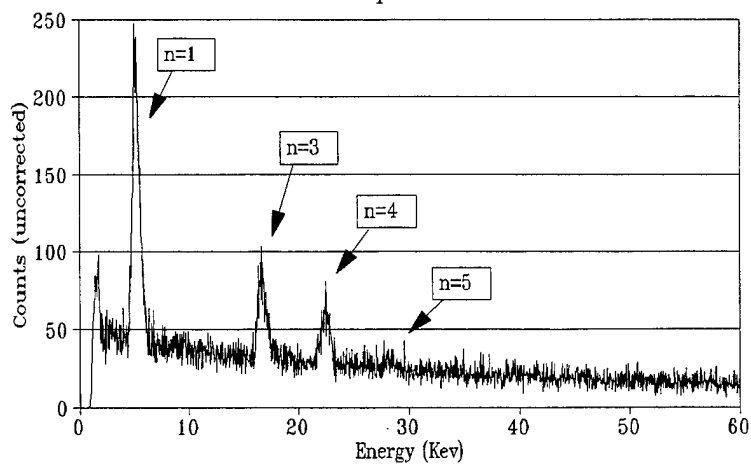
C8. UNCORRECTED SILICON DATA TAKEN 05 SEPTEMBER 1991

44 um Si Crystal <111>
5 Sep 1991

44 um Si Crystal 5 Sep 91
Gauss1(544.935, 4.95503, 0.281639)
Exp2(69.9513, 15.5928) Gauss3(34.9416, 16.3819, 0.256504)
Gauss4(12.6497, 22.2515, 0.426017)
Bkgnd(29.0416) X2=209729.65 r2=0.9600766

PeakFit Numerical Summary

Description: 44 um Si Crystal 5 Sep 91
X-Y Table Size: 2048   Active Points: 923
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI905T44.PRN

Curve-Fit Std Error= 15.1729743   r2= 0.960076604

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	29.041573			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	544.93525	4.9550302	0.2816395		
2	Exp	69.951318	15.592822			
3	Gaussian	34.941649	16.381926	0.2565041		
4	Gaussian	12.649703	22.251488	0.4260173		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	544.93525	4.9550302	0.6632101	384.70494	91.448514
2	Exp	0	0	0	0	0
3	Gaussian	34.941649	16.381926	0.6040203	22.466128	5.340441
4	Gaussian	12.649703	22.251488	1.0031935	13.5082	3.2110448
	Total				420.67927	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
544.9352515	4.955030226	0.663210116	384.7049424
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.623425247	5.286635363	0.331604979	0.331605137

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	544.9352515	4.893621026	111.3562429	535.3410223	554.5294806
Ctr	4.955030226	0.002872255	1725.136103	4.949399003	4.960661448
Wid1	0.281639493	0.003023659	93.14526963	0.275711434	0.287567552

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	69.95131838	2.792742189	25.04753882	64.47598458	75.42665217
Rte1	15.59282176	2.494084958	6.251920854	10.70302287	20.48262066

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
34.94164852	16.3819261	0.604020341	22.4661281
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
16.07991568	16.68393602	0.302010419	0.302009922

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	34.94164852	5.070183174	6.891594902	25.00125896	44.88203808
Ctr	16.3819261	0.042697596	383.6732662	16.29821498	16.46563723
Wid1	0.25650409	0.04352993	5.892591436	0.171161127	0.341847054

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
12.649703	22.25148775	1.003193512	13.50819971
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
21.7498909	22.75308441	0.501596852	0.50159666

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	12.649703	3.938357767	3.211923282	4.928323109	20.3710829
Ctr	22.25148775	0.152039024	146.3537922	21.95340638	22.54956911
Wid1	0.426017297	0.155433074	2.740840719	0.121281699	0.730752895

```
Background  Order=0      Area=894.38298495
  Parm     Value          Std Error      t-value       95% Confidence Limits
   a     29.041573      3.917369027   7.413540262   21.36134276  36.72180325


Total Peaks= 4    Coefficient Count= 12    Fitted Count=12
Std Error for Curve= 15.17297435      r2= 0.9600766039
Source    Sum of Squares     DF      Mean Square          F
Regr      5043572.1          11      458506.55            1991.61
Error     209729.65          911     230.21915
Total     5253301.7          922
```
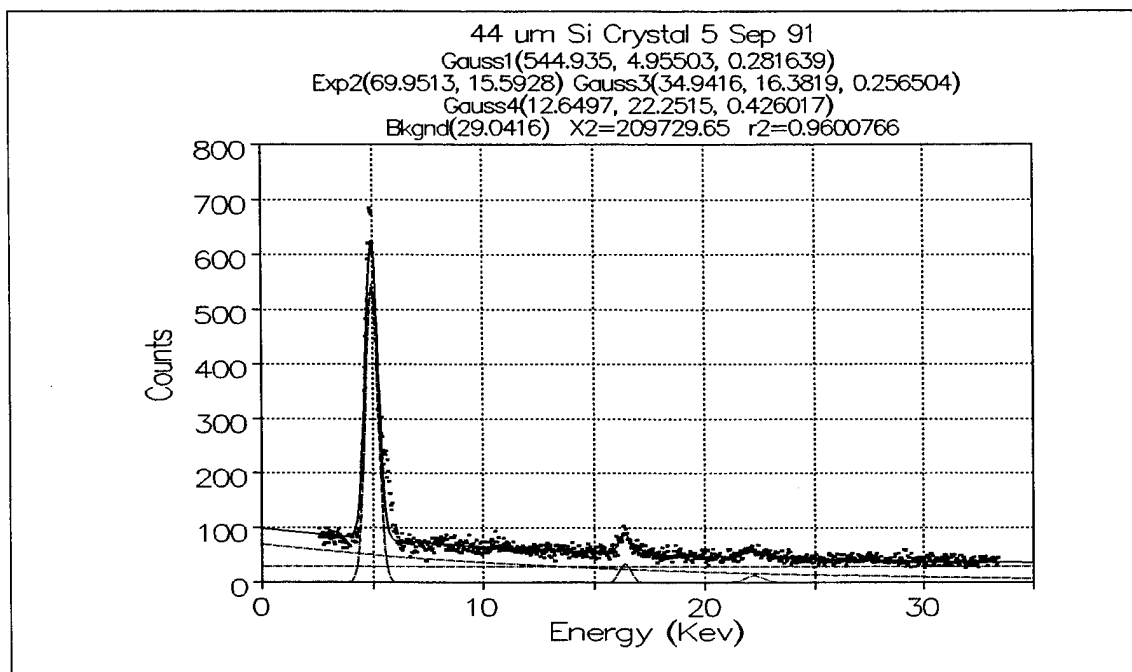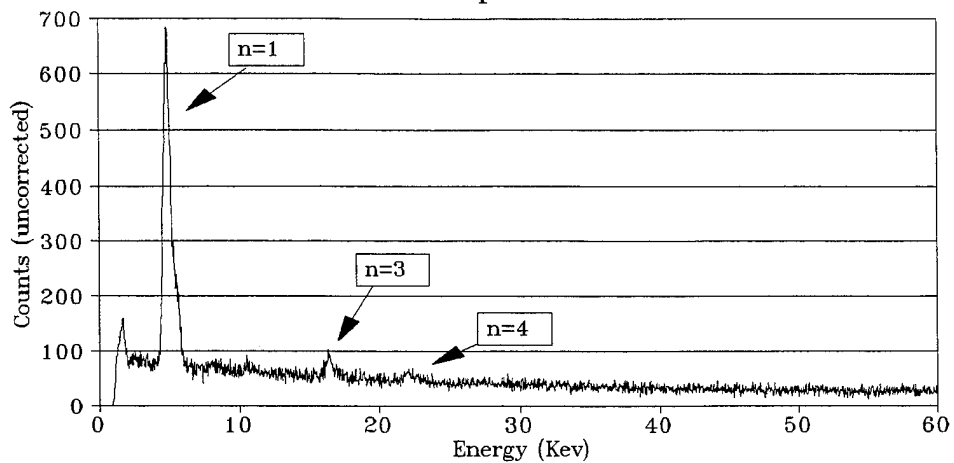
C9. UNCORRECTED SILICON DATA TAKEN 23 JULY 1991

20 um Si Crystal <111>
23 Jul 1991

20 um Si Crystal 23 Jul 91
Gauss1(756.889, 5.26116, 0.203201)
Gauss2(20.6772, 10.6954, 0.1734) Gauss3(18.4294, 16.0578, 0.319263)
Gauss4(10.0756, 21.506, 0.324297) Exp5(54.5967, 23.5123)
Bkgnd(8.21343) X2=52631.416 r2=0.9925355
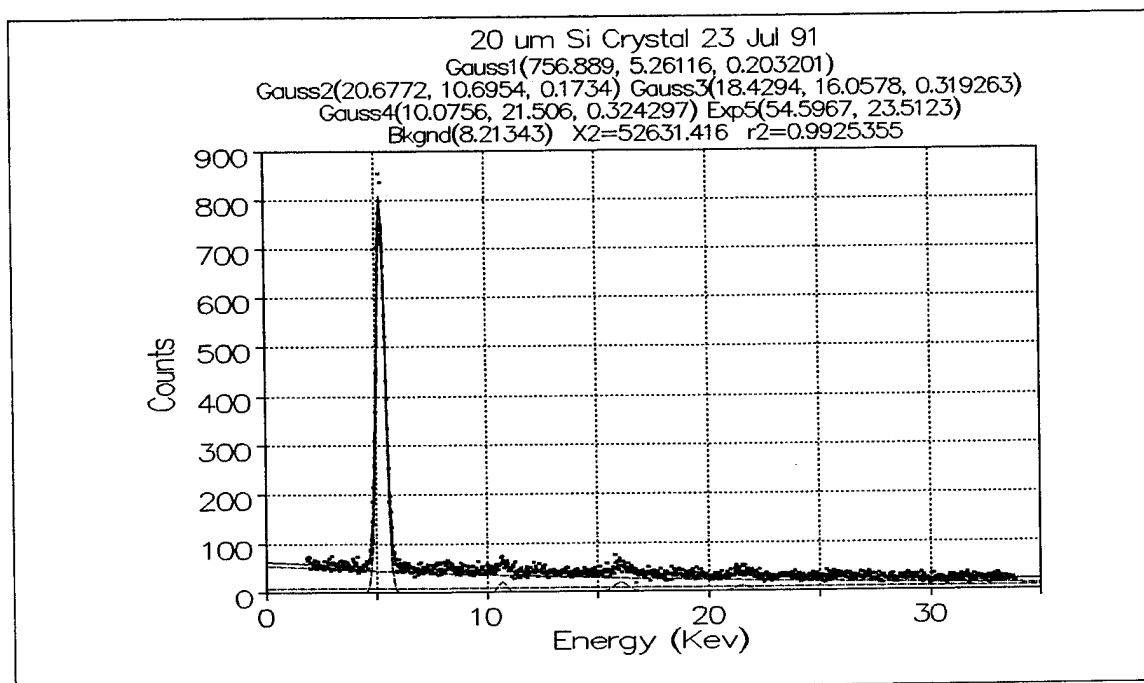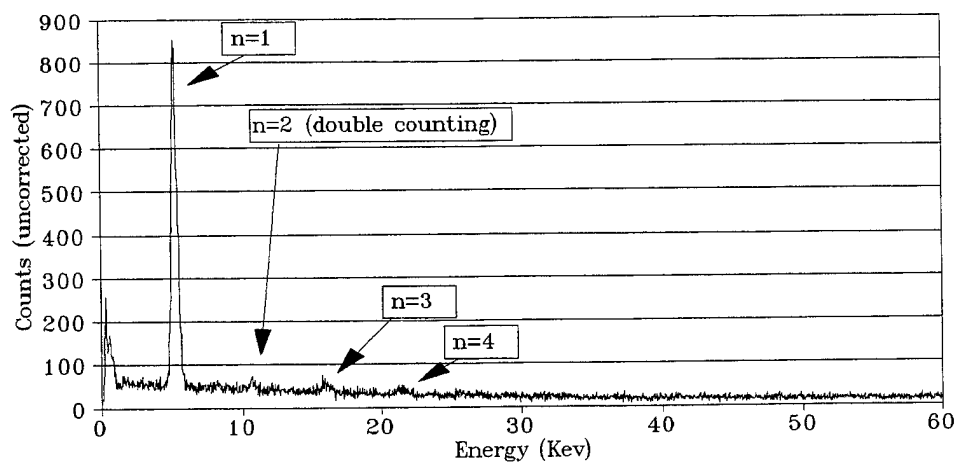
PeakFit Numerical Summary

Description: 20 um Si Crystal 23 Jul 91
X-Y Table Size: 2048   Active Points: 1032
X Variable: Energy (Kev)
Y Variable: Counts
File Source: SI723T20.PRN

Curve-Fit Std Error= 7.19386114   r2= 0.992535502

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 0	8.2134311			

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	756.8885	5.2611648	0.2032013		
2	Gaussian	20.677221	10.695353	0.1733997		
3	Gaussian	18.429441	16.057834	0.3192633		
4	Gaussian	10.075559	21.506047	0.3242974		
5	Exp	54.59671	23.512274			

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	756.8885	5.2611648	0.4785021	385.52123	92.352023
2	Gaussian	20.677221	10.695353	0.4083242	8.9873248	2.1529233
3	Gaussian	18.429441	16.057834	0.751806	14.748615	3.5330465
4	Gaussian	10.075559	21.506047	0.76366	8.1903513	1.9620074
5	Exp	0	0	0	0	0
	Total				417.44752	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
756.8885017	5.261164776	0.478502097	385.5212293
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
5.021913678	5.500415775	0.239251098	0.239250999

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	756.8885017	2.608136165	290.2028321	751.7768216	762.0001817
Ctr	5.261164776	0.000802261	6557.924037	5.259592428	5.262737125
Wid1	0.203201274	0.00082136	247.395967	0.201591491	0.204811056

Peak# 2 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
20.67722138	10.69535277	0.408324218	8.987324808
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
10.49119091	10.89951513	0.204161867	0.204162351

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	20.67722138	2.813280684	7.349860787	15.16347907	26.19096369
Ctr	10.69535277	0.027122363	394.3370584	10.64219572	10.74850983
Wid1	0.17339969	0.027479902	6.310054865	0.119541893	0.227257486

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
18.42944062	16.05783379	0.751805995	14.74861512
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.68193073	16.43373672	0.375903058	0.375902936

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	18.42944062	2.082379474	8.850183578	14.34818991	22.51069134
Ctr	16.05783379	0.041292185	388.8831225	15.97690533	16.13876225
Wid1	0.319263303	0.042364096	7.536176396	0.236234008	0.402292597

```
Peak# 4  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  10.07555931   21.50604701   0.763659952   8.190351324
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  21.12421788   21.88787783   0.38182913    0.381830823
 Parm  Value         Std Error     t-value        95% Confidence Limits
 Ampl  10.07555931   2.061223608   4.888144727    6.035771925   14.1153467
  Ctr  21.50604701   0.076126668   282.503459     21.35684653   21.65524749
 Widl  0.324297396   0.077567273   4.180853398    0.172273477   0.476321315

Peak# 5  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
 Parm  Value         Std Error     t-value        95% Confidence Limits
 Ampl  54.59670971   2.868483876   19.03329845    48.97477479   60.21864463
 Rtel  23.51227448   3.143771039   7.47900346     17.35080489   29.67374407

Background  Order=0    Area=263.00908591
 Parm    Value         Std Error     t-value        95% Confidence Limits
   a     8.213431091   3.590901286   2.287289579    1.175631959   15.25123022

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 7.193861135      r2= 0.9925355017
Source    Sum of Squares    DF      Mean Square        F
Regr      6998266.6         14      499876.18          9659.14
Error     52631.416         1017    51.751638
Total     7050898           1031
```

APPENDIX D. ATTENUATION COEFFICIENT PROGRAMS

Attenuation coefficients were used to correct the PXR spectrums. These attenuation coefficients were calculated by XCOM running on a personal computer [Ref. 16]. Running XCOM manually for each energy channel of each data file would have been very tedious so various QBasic and MS-DOS command files were written to speed up the process.

The first step in the process is to generate energy list files to tell XCOM at what energies to calculate coefficients. This is accomplished by the following program ENLIST.BAS:

```
ENLIST.BAS
REM QBASIC PROGRAM TO SAVE ENERGY GRID FOR XCOM
REM BY LT JOE THIEN
CLS
DIM E(2050)
INPUT "File name to save"; INFILE$
REM OPEN FILES
OPEN "C:\THESIS\COR\" + INFILE$ + "1.XCM" FOR OUTPUT AS #1
OPEN "C:\THESIS\COR\" + INFILE$ + "2.XCM" FOR OUTPUT AS #2
OPEN "C:\THESIS\COR\" + INFILE$ + "3.XCM" FOR OUTPUT AS #3
OPEN "C:\THESIS\COR\" + INFILE$ + "4.XCM" FOR OUTPUT AS #4
OPEN "C:\THESIS\COR\" + INFILE$ + "5.XCM" FOR OUTPUT AS #5
REM VARIABLE LIST
REM   M           - SLOPE OF LINE
REM   B           - CONSTANT
REM   COUNTS      - NUMBER ABOVE 0
REM   E ( )       - ENERGY ARRAY
REM INPUT M AND B
INPUT "X Coefficient"; M
INPUT "Constant"; B
REM REPEAT STEP FIVE TIMES
REM CALCULATE ENERGIES
COUNT = 0
FOR X = 0 TO 400
Y = M * X + B
IF Y > 0 THEN
COUNT = COUNT + 1
E(X) = Y / 1000
END IF
NEXT X
REM STORE ENERGIES
WRITE #1, COUNT
```

```
FOR X = 0 TO 400
IF E(X) > 0 THEN
PRINT #1, E(X); " "
END IF
NEXT X
REM SECOND
REM CALCULATE ENERGIES
COUNT = 0
FOR X = 401 TO 800
Y = M * X + B
COUNT = COUNT + 1
E(X) = Y / 1000
NEXT X
REM STORE ENERGIES
WRITE #2, COUNT
FOR X = 401 TO 800
PRINT #2, E(X); " "
NEXT X
REM THIRD
REM CALCULATE ENERGIES
COUNT = 0
FOR X = 801 TO 1200
Y = M * X + B
COUNT = COUNT + 1
E(X) = Y / 1000
NEXT X
REM STORE ENERGIES
WRITE #3, COUNT
FOR X = 801 TO 1200
PRINT #3, E(X); " "
NEXT X
REM FOURTH
REM CALCULATE ENERGIES
COUNT = 0
FOR X = 1201 TO 1600
Y = M * X + B
COUNT = COUNT + 1
E(X) = Y / 1000
NEXT X
REM STORE ENERGIES
WRITE #4, COUNT
FOR X = 1201 TO 1600
PRINT #4, E(X); " "
NEXT X
REM FIFTH
REM CALCULATE ENERGIES
COUNT = 0
FOR X = 1601 TO 2047
Y = M * X + B
COUNT = COUNT + 1
E(X) = Y / 1000
NEXT X
REM STORE ENERGIES
WRITE #5, COUNT
FOR X = 1601 TO 2047
PRINT #5, E(X); " "
NEXT X
REM CLOSE FILES
CLOSE
END
```

The next step is to run MAKECMD.BAS which generates the proper command files which will provide inputs to XCOM.

MAKECMD.BAS

```
DECLARE SUB CMNSTF ()
REM THIS QBASIC PROGRAM WRITES THE CMD FILES FOR EXCOM.BAT
REM BY LT JOE THIEN
CLS
REM OPEN FILES
OPEN "C:\THESIS\CMD1" FOR OUTPUT AS #1
OPEN "C:\THESIS\CMD2" FOR OUTPUT AS #2
OPEN "C:\THESIS\CMD3" FOR OUTPUT AS #3
OPEN "C:\THESIS\CMD4" FOR OUTPUT AS #4
OPEN "C:\THESIS\CMD5" FOR OUTPUT AS #5
OPEN "C:\THESIS\CMD6" FOR OUTPUT AS #6
REM INPUT ENERGY LIST
INPUT "Energy File Prefix?"; IN$
REM INPUT SUBSTANCE
START: INPUT "Substance? (A - Air, B - Be, K - Kapton, S - Si)"; SUB$
IF SUB$ = "A" THEN
FOR X = 1 TO 5
PRINT #X, "Air"
PRINT #X, "4"
PRINT #X, "4"
PRINT #X, "N2"
PRINT #X, ".7575"
PRINT #X, "O2"
PRINT #X, ".23"
PRINT #X, "Ar"
PRINT #X, ".012"
PRINT #X, "CO2"
PRINT #X, ".0005"
PRINT #X, "1"
CALL CMNSTF
NEXT X
ELSEIF SUB$ = "B" THEN
FOR X = 1 TO 5
PRINT #X, "Be"
PRINT #X, "2"
PRINT #X, "Be"
PRINT #X, "3"
CALL CMNSTF
NEXT X
ELSEIF SUB$ = "K" THEN
FOR X = 1 TO 5
PRINT #X, "Kapton"
PRINT #X, "3"
PRINT #X, "C22O5N2H10"
CALL CMNSTF
NEXT X
ELSEIF SUB$ = "S" THEN
FOR X = 1 TO 5
PRINT #X, "Si"
PRINT #X, "2"
PRINT #X, "Si"
PRINT #X, "3"
CALL CMNSTF
NEXT X
ELSE
```

```
PRINT "TRY AGAIN"
GOTO START
END IF
REM MAKE COMBINE FILE
PRINT #6, IN$ + SUB$
CLOSE
END

SUB CMNSTF
SHARED X, IN$, SUB$
IF X = 1 THEN X$ = "1"
IF X = 2 THEN X$ = "2"
IF X = 3 THEN X$ = "3"
IF X = 4 THEN X$ = "4"
IF X = 5 THEN X$ = "5"
PRINT #X, "3"
PRINT #X, "2"
PRINT #X, "C:\THESIS\COR\" + IN$ + X$ + ".XCM"
PRINT #X, "3"
PRINT #X, "C:\THESIS\COR\" + IN$ + SUB$ + X$ + ".XCM"
PRINT #X, "1"
END SUB
```

Typical generated command files follow:

CMD1

```
Air
4
4
N2
.7575
O2
.23
Ar
.012
CO2
.0005
1
3
2
C:\THESIS\COR\S930E1.XCM
3
C:\THESIS\COR\S930EA1.XCM
1
```

CMD2

```
Air
4
4
N2
.7575
O2
.23
Ar
.012
CO2
.0005
1
```

114

```
3
2
C:\THESIS\COR\S930E2.XCM
3
C:\THESIS\COR\S930EA2.XCM
1
```

CMD3

```
Air
4
4
N2
.7575
O2
.23
Ar
.012
CO2
.0005
1
3
2
C:\THESIS\COR\S930E3.XCM
3
C:\THESIS\COR\S930EA3.XCM
1
```

CMD4

```
Air
4
4
N2
.7575
O2
.23
Ar
.012
CO2
.0005
1
3
2
C:\THESIS\COR\S930E4.XCM
3
C:\THESIS\COR\S930EA4.XCM
1
```

CMD5

```
Air
4
4
N2
.7575
O2
.23
Ar
.012
```

```
CO2
.0005
1
3
2
C:\THESIS\COR\S930E5.XCM
3
C:\THESIS\COR\S930EA5.XCM
1
```

CMD6

```
S930EA
```

These command files generate 5 separate files of attenuation coefficients that are then

combined into one file by the QBasic program COMBINE.BAS with the file name given

by the CMD6 file.

COMBINE.BAS
```
REM QBASIC FILE TO COMBINE XCOM FILES INTO ONE FILE FOR Q PRO
REM BY LT JOE THIEN
CLS
INPUT "File name to work on (name only)"; INFILE$
REM OPEN FILES
OPEN "C:\THESIS\COR\" + INFILE$ + "1.XCM" FOR INPUT AS #1
OPEN "C:\THESIS\COR\" + INFILE$ + "2.XCM" FOR INPUT AS #2
OPEN "C:\THESIS\COR\" + INFILE$ + "3.XCM" FOR INPUT AS #3
OPEN "C:\THESIS\COR\" + INFILE$ + "4.XCM" FOR INPUT AS #4
OPEN "C:\THESIS\COR\" + INFILE$ + "5.XCM" FOR INPUT AS #5
OPEN "C:\THESIS\COR\" + INFILE$ + ".XCM" FOR OUTPUT AS #6
REM DO FIRST FILE
REM DO FIRST PAGE
FOR X = 1 TO 13
LINE INPUT #1, A$
NEXT X
FOR X = 1 TO 44
INPUT #1, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
NEXT X
REM DO REST OF PAGES
DO
FOR X = 1 TO 14
LINE INPUT #1, A$
IF EOF(1) = -1 THEN EXIT DO
NEXT X
FOR X = 1 TO 44
INPUT #1, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
IF EOF(1) = -1 THEN EXIT DO
NEXT X
LOOP
REM DO SECOND FILE
REM DO FIRST PAGE
```

```
FOR X = 1 TO 13
LINE INPUT #2, A$
NEXT X
FOR X = 1 TO 44
INPUT #2, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
NEXT X
REM DO REST OF PAGES
DO
FOR X = 1 TO 14
LINE INPUT #2, A$
IF EOF(2) = -1 THEN EXIT DO
NEXT X
FOR X = 1 TO 44
INPUT #2, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
IF EOF(2) = -1 THEN EXIT DO
NEXT X
LOOP
REM DO THIRD FILE
REM DO FIRST PAGE
FOR X = 1 TO 13
LINE INPUT #3, A$
NEXT X
FOR X = 1 TO 44
INPUT #3, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
NEXT X
REM DO REST OF PAGES
DO
FOR X = 1 TO 14
LINE INPUT #3, A$
IF EOF(3) = -1 THEN EXIT DO
NEXT X
FOR X = 1 TO 44
INPUT #3, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
IF EOF(3) = -1 THEN EXIT DO
NEXT X
LOOP
REM DO FOURTH FILE
REM DO FIRST PAGE
FOR X = 1 TO 13
LINE INPUT #4, A$
NEXT X
FOR X = 1 TO 44
INPUT #4, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
NEXT X
REM DO REST OF PAGES
DO
FOR X = 1 TO 14
LINE INPUT #4, A$
IF EOF(4) = -1 THEN EXIT DO
NEXT X
FOR X = 1 TO 44
INPUT #4, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
IF EOF(4) = -1 THEN EXIT DO
NEXT X
LOOP
REM DO FIFTH FILE
```

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```
REM DO FIRST PAGE
FOR X = 1 TO 13
LINE INPUT #5, A$
NEXT X
FOR X = 1 TO 44
INPUT #5, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
NEXT X
REM DO REST OF PAGES
DO
FOR X = 1 TO 14
LINE INPUT #5, A$
IF EOF(5) = -1 THEN EXIT DO
NEXT X
FOR X = 1 TO 44
INPUT #5, A1, A2, A3, A4, A5, A6, A7, A8
WRITE #6, A1, A7
IF EOF(5) = -1 THEN EXIT DO
NEXT X
LOOP
REM CLOSE FILES
CLOSE
END
```

The batch file that runs XCOM using the command files and then combines the

files into one file of attenuation coefficients is EXCOM.BAT.

EXCOM.BAT
```
cd xcomm
xcom < c:\thesis\cmd1
xcom < c:\thesis\cmd2
xcom < c:\thesis\cmd3
xcom < c:\thesis\cmd4
xcom < c:\thesis\cmd5
qbasic /run c:\thesis\baspro\combine < c:\thesis\cmd6
```

The file of attenuation coefficients generated is then imported into the spreadsheet

file containing the PXR spectrum data where the corrected counts are then calculated.

APPENDIX E. CORRECTED PXR DATA

This appendix contains the corrected PXR spectrums and the Peakfit graphical and numerical analysis of the spectrums.

Section	Date	Beam Energy	Target
E1	25 Sep 92	96 MeV	1.75mm Si
E2	29-30 Sep 92	96 MeV	1.75mm Si
E3	02 Dec 92	91 MeV	1.75mm Si
E4	01 Dec 92	92 MeV	1mm LiF
E5	03 Dec 92	62 MeV	1mm LiF
E6	22 Oct 92	95 MeV	1mm LiF
E7	05 Sep 91	85 MeV	320μm Si
E8	05 Sep 91	85 MeV	44μm Si
E9	23 Jul 91	85 MeV	20μm Si

Table 13. Corrected PXR Data.

Sections E7, E8 and E9 are reanalysis of PXR spectrums reported on in Reference 5.

E1. CORRECTED SILICON DATA TAKEN 25 SEPTEMBER 1992

1.75 mm SI Crystal <111>
25 Sep 1992

1.75 mm SI Crystal 25 Sep 92
Exp1(26.0294, −38010.6) Exp2(200.238, 3.16141)
Gauss3(79.2124, 5.14247, 0.154465) Gauss4(17.1092, 15.4808, 0.286906)
Gauss5(12.1449, 20.5872, 0.286978) Gauss6(4.15357, 25.6471, 0.39686)
No Background X2=64975.572 r2=0.87659975
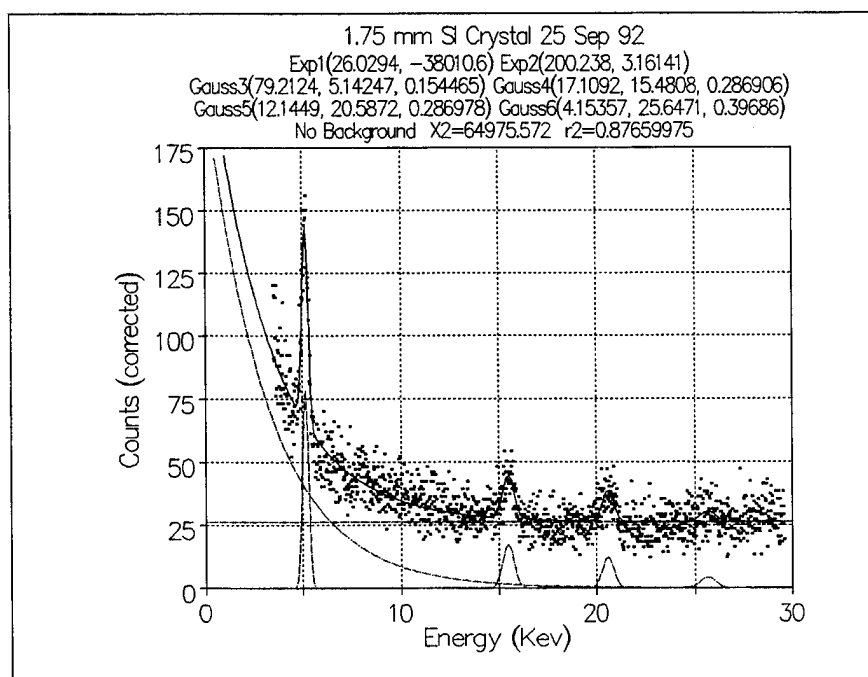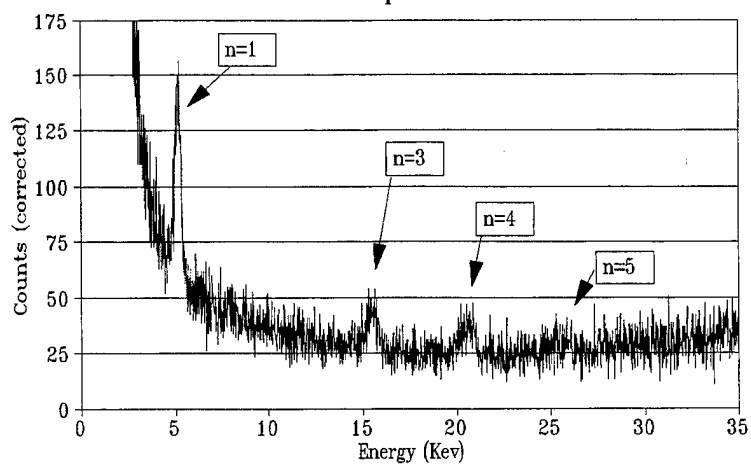
PeakFit Numerical Summary

Description: 1.75 mm SI Crystal 25 Sep 92
X-Y Table Size: 1970   Active Points: 1383
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S925X04.PRN

Curve-Fit Std Error= 6.89430984   r2= 0.876599746

Curve-Fit Coefficients

Peak#	Type	Amp1	Rte1	Amp2	Rte2
1	Exp	26.029414	-3.8e+04		
2	Exp	200.23753	3.161406		
3	Gaussian	79.212415	5.1424715	0.1544654	
4	Gaussian	17.109202	15.480849	0.2869062	
5	Gaussian	12.144866	20.587158	0.2869778	
6	Gaussian	4.1535694	25.64711	0.3968604	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Exp	0	0	0	0	0
3	Gaussian	79.212415	5.1424715	0.3637379	30.670054	54.922234
4	Gaussian	17.109202	15.480849	0.6756114	12.304374	22.033992
5	Gaussian	12.144866	20.587158	0.6757783	8.7363695	15.644607
6	Gaussian	4.1535694	25.64711	0.9345325	4.1318939	7.3991668
	Total				55.842691	100

Peak# 1 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	26.02941372	1.593080057	16.33904938	22.91016809	29.14865936
Rte1	-38010.5736	3.7999e+06	-0.01000306	-7.4782e+06	7.40217e+06

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	200.237529	10.47096613	19.12311877	179.7354109	220.7396471
Rte1	3.161405963	0.155264428	20.36143112	2.857398711	3.465413215

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
79.21241479	5.14247151	0.363737903	30.67005359
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.960602694	5.324340597	0.181868816	0.181869087

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	79.21241479	2.248162225	35.23429667	74.81052037	83.6143092
Ctr	5.14247151	0.005000662	1028.358149	5.13268023	5.15226279
Wid1	0.154465425	0.00519876	29.71197218	0.144286268	0.164644581

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
17.10920164	15.48084927	0.675611409	12.30437411
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.14304343	15.81865484	0.337805844	0.337805564

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	17.10920164	1.645359572	10.39845753	13.88759288	20.3308104
Ctr	15.48084927	0.031498122	491.4848273	15.41917605	15.5425225
Wid1	0.286906155	0.03255662	8.812528777	0.223160396	0.350651913

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```
Peak# 5  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  12.14486586   20.58715792    0.675778313   8.736369496
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  20.24926921   20.92504752    0.33788871    0.337889603
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  12.14486586    1.639557808    7.407403267    8.93461694    15.35511478
  Ctr   20.58715792    0.044384676    463.8348156    20.50025287   20.67406297
  Widl  0.28697777     0.04544403     6.314971885    0.197998506   0.375957034

Peak# 6  Gaussian
  PkAmpl        PkCtr          Wid@HM        Area
  4.153569401   25.64711001    0.934532456   4.131893877
  XL @HM        XR @HM         Ctr-XL@HM     Ctr-XR@HM
  25.17984292   26.11437538    0.467267082   0.467265374
  Parm  Value          Std Error      t-value        95% Confidence Limits
  Ampl  4.153569401    1.406971917    2.952133835    1.398722906   6.908415896
  Ctr   25.64711001    0.152730479    167.9239808    25.34806422   25.94615579
  Widl  0.396860384    0.160407639    2.474074093    0.082782742   0.710938025


Total Peaks= 6   Coefficient Count= 16   Fitted Count=16
Std Error for Curve= 6.894309843      r2= 0.8765997465
Source    Sum of Squares    DF      Mean Square         F
Regr      461567.69         15      30771.179           647.385
Error     64975.572         1367    47.531508
Total     526543.26         1382
```

E2. CORRECTED SILICON DATA TAKEN 29-30 SEPTEMBER 1992

1.75 mm Si Crystal <111> (Sn Backing)
29 - 30 Sep 1992

1.75 mm Si Crystal 29-30 Sep 92
Exp1(12.1222, -16.7473) Exp2(16458.7, 0.701906)
Gauss3(153.263, 5.08211, 0.242281) Exp4(212.911, 10.4938)
Gauss5(41.4336, 15.3568, 0.27868) Gauss6(32.839, 20.4024, 0.359541)
Gauss7(10.1636, 25.3107, 0.4709) Bkgnd(0.00305559) X2=208424.75 r2=0.94042469

```
                        PeakFit Numerical Summary


Description: 1.75 mm SI Crystal 29-30 Sep 92
X-Y Table Size: 1965   Active Points: 1481
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S930X13.PRN


Curve-Fit Std Error= 11.9399074     r2= 0.940424692


Background Coefficients [y=a+bx+cx^2+dx^3]
Background          a           b           c           d
      Order= 0    0.0030556


Curve-Fit Coefficients
Peak#  Type      Ampl        Rtel       Amp2        Rte2
  1  Exp        12.122162   -16.74733
  2  Exp        1.646e+04   0.7019065
  3  Gaussian   153.2625    5.0821085   0.2422811
  4  Exp        212.91071   10.493779
  5  Gaussian   41.433593   15.356805   0.2786795
  6  Gaussian   32.838982   20.402398   0.3595408
  7  Gaussian   10.163553   25.310678   0.4708995


Measured Values
Peak#  Type      PkAmpl      PkCtr       Wid@HM      Area        %Area
  1  Exp        0           0           0           0           0
  2  Exp        0           0           0           0           0
  3  Gaussian   153.2625    5.0821085   0.5705279   93.077668   56.888801
  4  Exp        0           0           0           0           0
  5  Gaussian   41.433593   15.356805   0.6562393   28.943256   17.690034
  6  Gaussian   32.838982   20.402398   0.8466525   29.595644   18.088772
  7  Gaussian   10.163553   25.310678   1.108881    11.996774   7.3323936
     Total                                          163.61334   100


Peak# 1  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  12.12216203   74.26979639   0.163217925   -133.26298    157.507304
  Rtel  -16.747331    35.26316404   -0.47492423   -85.7759316   52.28126964


Peak# 2  Exp
  PkAmpl        PkCtr         Wid@HM        Area
  0             0             0             0
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  0             0             0             0
  Parm  Value         Std Error     t-value       95% Confidence Limits
  Ampl  16458.66777   6249.162674   2.633739692   4225.762246   28691.5733
  Rtel  0.701906466   0.059569993   11.78288652   0.585296589   0.818516344


Peak# 3  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  153.2625006   5.082108483   0.57052792    93.07766787
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  4.796844698   5.367372618   0.285263785   0.285264135
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  153.2625006   3.189301189   48.05519816    147.019357    159.5056442
   Ctr  5.082108483   0.005618231   904.5744836    5.071110643   5.093106323
  Widl  0.242281095   0.006299214   38.46211565    0.229950213   0.254611977
```

```
Peak# 4   Exp
  PkAmpl          PkCtr           Wid@HM          Area
  0               0               0               0
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  0               0               0               0
  Parm  Value          Std Error       t-value       95% Confidence Limits
  Ampl  212.9107053    106.8632468     1.992366053   3.72299949    422.0984111
  Rtel  10.49377862    7.541573357     1.391457475   -4.2690559    25.25661314

Peak# 5   Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  41.43359267     15.35680535     0.65623935      28.94325591
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  15.02868592     15.68492527     0.328119425     0.328119924
  Parm  Value          Std Error       t-value       95% Confidence Limits
  Ampl  41.43359267    2.83287281      14.62599822   35.88816726   46.97901808
  Ctr   15.35680535    0.021676455     708.4555853   15.3143731    15.3992376
  Widl  0.278679513    0.022635836     12.31143024   0.23436925    0.322989776

Peak# 6   Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  32.83898217     20.40239839     0.846652511     29.59564392
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  19.97907214     20.82572465     0.42332625      0.423326261
  Parm  Value          Std Error       t-value       95% Confidence Limits
  Ampl  32.83898217    2.506833033     13.09978835   27.93178848   37.74617587
  Ctr   20.40239839    0.031122897     655.5430414   20.34147447   20.4633223
  Widl  0.359540816    0.0328834       10.93380898   0.295170667   0.423910964

Peak# 7   Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  10.16355297     25.31067835     1.108881012     11.9967742
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  24.75623736     25.86511837     0.554440998     0.554440014
  Parm  Value          Std Error       t-value       95% Confidence Limits
  Ampl  10.16355297    2.258453449     4.500226903   5.742569054   14.58453689
  Ctr   25.31067835    0.115258579     219.5990846   25.08505656   25.53630015
  Widl  0.470899542    0.129421478     3.638496104   0.217553487   0.724245597

Background  Order=0    Area=0.08123364874
  Parm    Value        Std Error       t-value       95% Confidence Limits
  a       0.003055592  203.5509924     1.50114e-05   -398.453536   398.4596474

Total Peaks= 7   Coefficient Count= 19   Fitted Count=19
Std Error for Curve= 11.93990743      r2= 0.9404246919
Source    Sum of Squares   DF      Mean Square        F
Regr      3290084.2        18      182782.46          1282.13
Error     208424.75        1462    142.56139
Total     3498509          1480
```
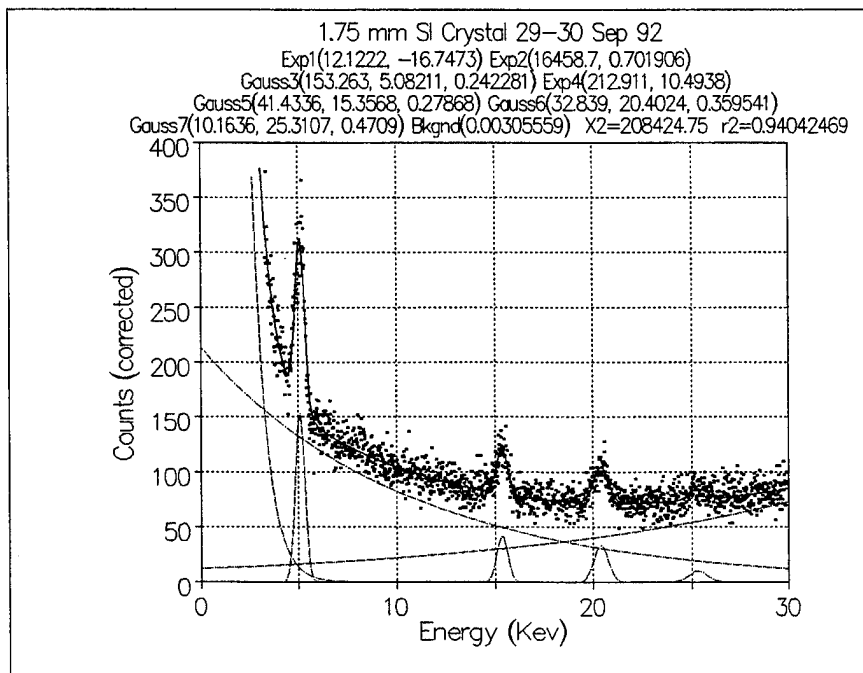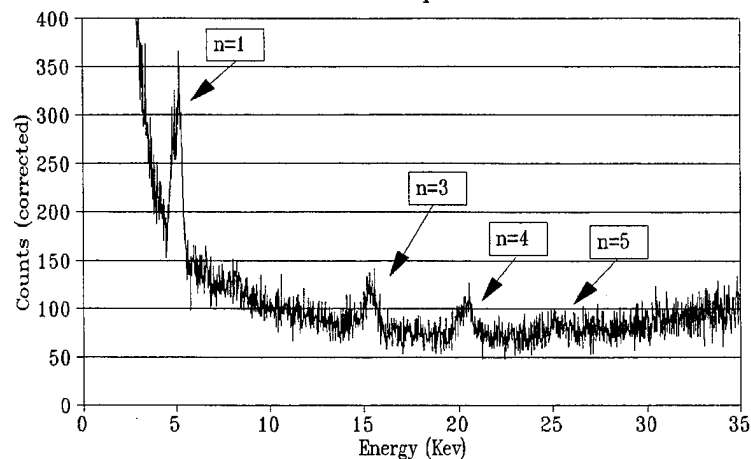
125

E3. CORRECTED SILICON DATA TAKEN 02 DECEMBER 1992

1.75 mm Si Crystal <111>
02 Dec 1992

1.75 mm SI Crystal 12 Dec 92
Exp1(13.8602, −35.656) Exp2(171.841, 4.30528)
Gauss3(165.105, 5.42328, 0.175275) Gauss4(44.1799, 15.7513, 0.296049)
Gauss5(34.326, 21.0178, 0.350812) Gauss6(8.43147, 26.4196, 0.362674)
Gauss7(18.4784, 41.8525, 0.130724) No Background X2=104065.22 r2=0.83390763
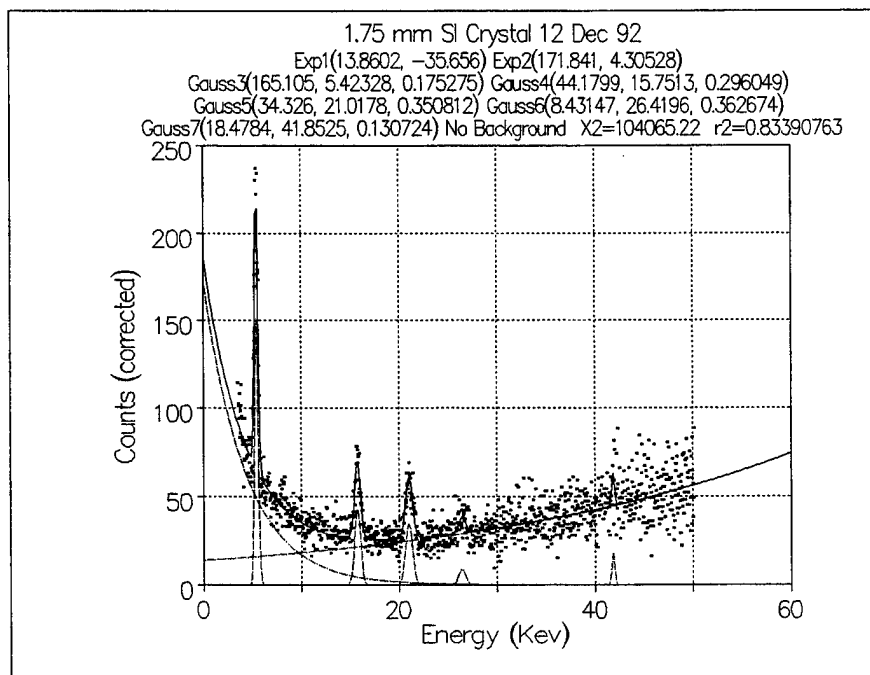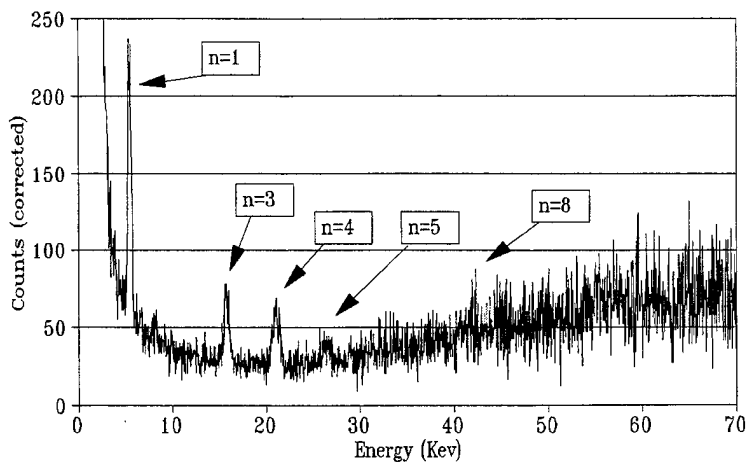
PeakFit Numerical Summary

Description: 1.75 mm SI Crystal 02 Dec 92
X-Y Table Size: 1997   Active Points: 1258
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S1202Y2.PRN

Curve-Fit Std Error= 9.16467663   r2= 0.83390763

Curve-Fit Coefficients

Peak#	Type	Ampl	Rte1	Amp2	Rte2
1	Exp	13.860178	-35.65605		
2	Exp	171.84102	4.3052752		
3	Gaussian	165.10457	5.4232754	0.1752754	
4	Gaussian	44.179879	15.751283	0.2960488	
5	Gaussian	34.325985	21.01775	0.350812	
6	Gaussian	8.4314709	26.419642	0.3626737	
7	Gaussian	18.47842	41.852522	0.1307236	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Exp	0	0	0	0	0
3	Gaussian	165.10457	5.4232754	0.4127413	72.538731	48.609154
4	Gaussian	44.179879	15.751283	0.6971407	32.785201	21.969792
5	Gaussian	34.325985	21.01775	0.8260983	30.184741	20.22719
6	Gaussian	8.4314709	26.419642	0.8540295	7.6649499	5.1363833
7	Gaussian	18.47842	41.852522	0.3078256	6.0549176	4.0574796
	Total				149.22854	100

Peak# 1 Exp

PkAmpl	PkCtr	Wid@HM	Area	
0	0	0	0	
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM	
0	0	0	0	

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	13.86017849	0.623624855	22.22518616	12.63871239	15.0816446
Rte1	-35.6560479	1.405974361	-25.3603827	-38.409867	-32.9022288

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area	
0	0	0	0	
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM	
0	0	0	0	

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	171.84102	8.750813846	19.63714724	154.7011924	188.9808476
Rte1	4.305275236	0.185919031	23.15672163	3.941123947	4.669426524

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
165.1045743	5.423275385	0.412741277	72.53873103
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
5.216904719	5.629645995	0.206370666	0.20637061

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	165.1045743	3.925379469	42.06079326	157.4161091	172.7930395
Ctr	5.423275385	0.004760157	1139.306087	5.413951879	5.432598891
Wid1	0.175275378	0.00492839	35.56442591	0.16562236	0.184928396

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
44.17987944	15.75128332	0.697140669	32.78520059
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
15.40271297	16.09985363	0.348570356	0.348570313

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	44.17987944	2.998991249	14.73157998	38.30588943	50.05386944
Ctr	15.75128332	0.023092129	682.1061662	15.7060538	15.79651284
Wid1	0.296048845	0.023435373	12.63256396	0.250147029	0.341950662

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```
Peak# 5  Gaussian
  PkAmpl       PkCtr         Wid@HM        Area
  34.32598528  21.01775002   0.826098335   30.184741
  XL @HM       XR @HM        Ctr-XL@HM     Ctr-XR@HM
  20.60470056  21.43079889   0.413049459   0.413048876
  Parm  Value          Std Error     t-value        95% Confidence Limits
  Ampl  34.32598528    2.758950904   12.44168036    28.92215156   39.729819
   Ctr  21.01775002    0.032350435   649.689875     20.95438667   21.08111337
  Wid1  0.350812044    0.032969116   10.64062622    0.286236911   0.415387178

Peak# 6  Gaussian
  PkAmpl       PkCtr         Wid@HM        Area
  8.43147095   26.41964186   0.85402949    7.664949866
  XL @HM       XR @HM        Ctr-XL@HM     Ctr-XR@HM
  25.99262708  26.84665657   0.427014773   0.427014716
  Parm  Value          Std Error     t-value        95% Confidence Limits
  Ampl  8.43147095     2.714731394   3.105821434    3.114248007   13.74869389
   Ctr  26.41964186    0.133907848   197.2971879    26.15736254   26.68192117
  Wid1  0.362673685    0.136663222   2.653776779    0.094997545   0.630349824

Peak# 7  Gaussian
  PkAmpl       PkCtr         Wid@HM        Area
  18.4784201   41.85252216   0.30782563    6.054917589
  XL @HM       XR @HM        Ctr-XL@HM     Ctr-XR@HM
  41.69860922  42.00643485   0.153912939   0.153912691
  Parm  Value          Std Error     t-value        95% Confidence Limits
  Ampl  18.4784201     4.49921355    4.10703335     9.666011782   27.29082842
   Ctr  41.85252216    0.036682513   1140.939345    41.78067376   41.92437055
  Wid1  0.130723607    0.03689476    3.543148343    0.058459492   0.202987723

Total Peaks= 7   Coefficient Count= 19   Fitted Count=19
Std Error for Curve= 9.164676633      r2= 0.8339076305
Source    Sum of Squares    DF      Mean Square         F
Regr      522485.05         18      29026.947           345.595
Error     104065.22         1239    83.991298
Total     626550.26         1257
```

E4. CORRECTED LITHIUM FLUORIDE DATA TAKEN 01 DECEMBER 1992

1 mm LiF Crystal <220>
1 Dec 1992
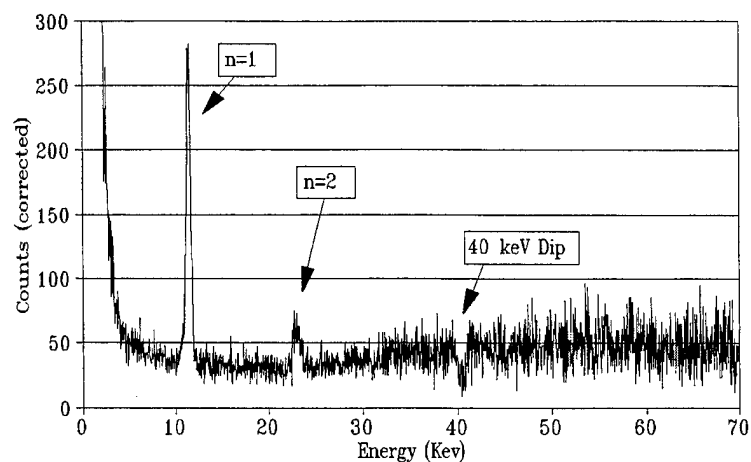
1 mm LiF Crystal 01 Dec 92
Exp1(21.1864, −56.2626)
Exp2(76.7779, 5.16148) Gauss3(238.725, 11.4256, 0.241795)
Gauss4(28.9298, 23.0234, 0.3717) Gauss5(−23.8163, 40.4535, 0.32618)
No Background X2=88342.843 r2=0.88255828
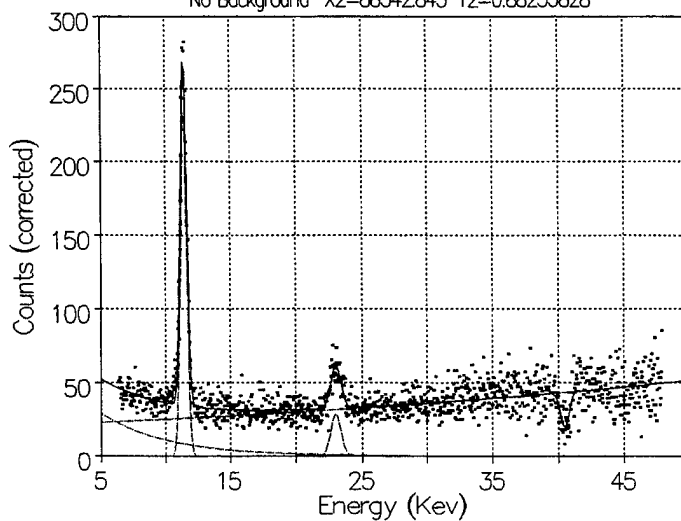
```
                        PeakFit Numerical Summary


Description: 1 mm LiF Crystal 01 Dec 92
X-Y Table Size: 2004    Active Points: 1130
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: L1201Y1.PRN


Curve-Fit Std Error= 8.89322131       r2= 0.882558281


Curve-Fit Coefficients
Peak#  Type       Ampl         Rte1         Amp2         Rte2
  1   Exp        21.18641     -56.26264
  2   Exp        76.777884     5.1614755
  3   Gaussian  238.72507     11.425575    0.2417947
  4   Gaussian   28.929756    23.023429    0.3717003
  5   Gaussian  -23.8163      40.453499    0.3261802


Measured Values
Peak#  Type      PkAmpl       PkCtr        Wid@HM       Area         %Area
  1   Exp        0            0            0            0            0
  2   Exp        0            0            0            0            0
  3   Gaussian  238.72507    11.425575    0.5693818    144.68876    95.083278
  4   Gaussian   28.929756   23.023429    0.8752858     26.954306   17.71322
  5   Gaussian  -23.8163     40.453499    0.7681003    -19.4725    -12.7965
      Total                                            152.17056    100
Peak# 1  Exp
  PkAmpl         PkCtr        Wid@HM       Area
  0              0            0            0
  XL @HM         XR @HM       Ctr-XL@HM    Ctr-XR@HM
  0              0            0            0
  Parm  Value          Std Error    t-value         95% Confidence Limits
  Ampl  21.18641035    1.207505209  17.54560576     18.82052274   23.55229796
  Rte1  -56.2626355    4.582864483  -12.27674       -65.2419279  -47.2833431


Peak# 2  Exp
  PkAmpl         PkCtr        Wid@HM       Area
  0              0            0            0
  XL @HM         XR @HM       Ctr-XL@HM    Ctr-XR@HM
  0              0            0            0
  Parm  Value          Std Error    t-value         95% Confidence Limits
  Ampl  76.77788448    18.02824112  4.258756247     41.45481343   112.1009555
  Rte1  5.161475525    0.904410951  5.707002463     3.389446181   6.933504869


Peak# 3  Gaussian
  PkAmpl         PkCtr        Wid@HM       Area
  238.7250704    11.42557523  0.569381806  144.6887598
  XL @HM         XR @HM       Ctr-XL@HM    Ctr-XR@HM
  11.14088438    11.71026619  0.284690847  0.284690959
  Parm  Value          Std Error    t-value         95% Confidence Limits
  Ampl  238.7250704    3.23062574   73.89437513     232.3952447   245.054896
  Ctr   11.42557523    0.003735816  3058.387725     11.41825557   11.43289488
  Wid1  0.241794718    0.003860361  62.63526858     0.234231041   0.249358395


Peak# 4  Gaussian
  PkAmpl         PkCtr        Wid@HM       Area
  28.92975592    23.02342917  0.875285763  26.95430645
  XL @HM         XR @HM       Ctr-XL@HM    Ctr-XR@HM
  22.58578704    23.4610728   0.43764213   0.437643633
  Parm  Value          Std Error    t-value         95% Confidence Limits
  Ampl  28.92975592    2.594275791  11.15138029     23.84674269   34.01276915
  Ctr   23.02342917    0.038218482  602.4161141     22.94854698   23.09831136
  Wid1  0.371700295    0.03902377   9.524971407     0.29524029    0.448160301
```

```
Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM         Area
  -23.8162952   40.45349852   0.768100277    -19.472503
  XL @HM        XR @HM        Ctr-XL@HM      Ctr-XR@HM
  40.06944741   40.83754768   0.384051114    0.384049164
 Parm  Value         Std Error      t-value        95% Confidence Limits
 Ampl  -23.8162952   2.765652225    -8.61145698    -29.2350895   -18.3975009
  Ctr  40.45349852   0.043489747    930.1847352    40.36828824   40.5387088
 Wid1  0.326180241   0.04424243     7.372566112    0.239495218   0.412865264

Total Peaks= 5   Coefficient Count= 13   Fitted Count=13
Std Error for Curve= 8.893221315      r2= 0.8825582811
Source    Sum of Squares    DF       Mean Square        F
Regr      663884.25         12       55323.688          699.508
Error     88342.843         1117     79.089385
Total     752227.1          1129
```

E5. CORRECTED LITHIUM FLUORIDE DATA TAKEN 03 DECEMBER 1992

1 mm LiF Crystal <220>
3 Dec 1992 (60 Mev Beam)

1 mm LiF Crystal 03 Dec 92
Exp1(10.0014, −42.9889) Exp2(89.9223, 4.43987)
Gauss3(61.5593, 11.283, 0.353975) Gauss4(10.0661, 22.9888, 0.05491)
Gauss5(55.8671, 32.4567, 0.0120098) Gauss6(−3.82869, 37.2229, 0.462594)
No Background X2=37205.248 r2=0.66333024
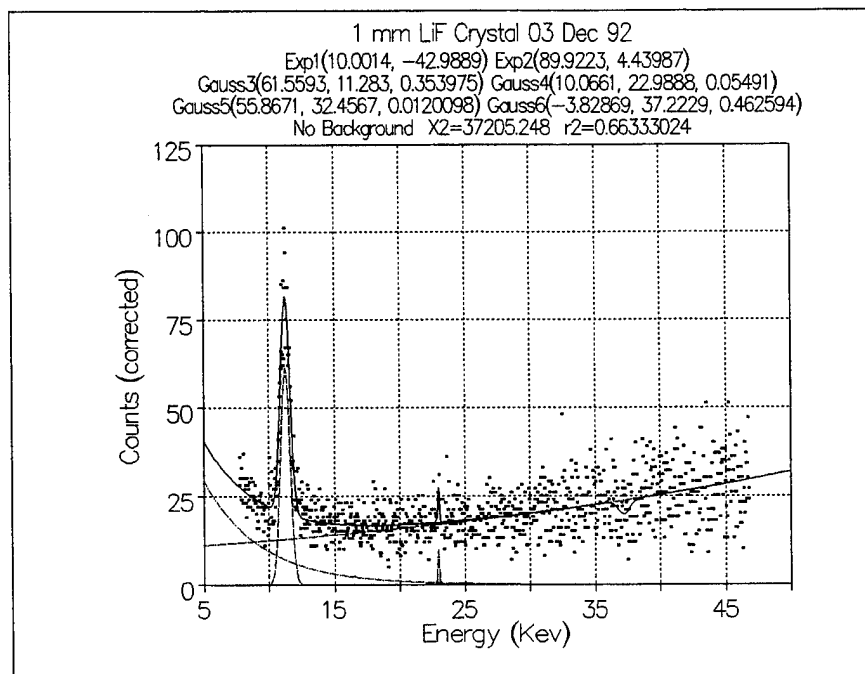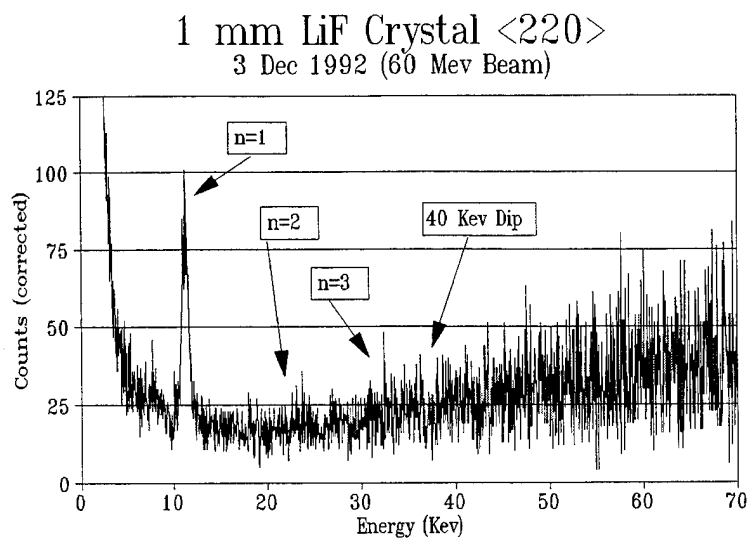
PeakFit Numerical Summary

Description: 1 mm LiF Crystal 03 Dec 92
X-Y Table Size: 1952   Active Points: 1033
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: L1203Y1.PRN

Curve-Fit Std Error= 6.04841558   r2= 0.663330244

Curve-Fit Coefficients

Peak#	Type	Ampl	Rtel	Amp2	Rte2
1	Exp	10.001403	-42.98892		
2	Exp	89.922291	4.4398657		
3	Gaussian	61.559312	11.283016	0.3539753	
4	Gaussian	10.066107	22.988784	0.05491	
5	Gaussian	55.867064	32.456654	0.0120098	
6	Gaussian	-3.828691	37.222922	0.4625939	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Exp	0	0	0	0	0
3	Gaussian	61.559312	11.283016	0.8335473	54.620635	102.57707
4	Gaussian	10.066107	22.988784	0.1293006	1.3854892	2.6019366
5	Gaussian	55.867064	32.456654	0.0282783	1.6818235	3.1584497
6	Gaussian	-3.828691	37.222922	1.0893306	-4.439562	-8.337459
	Total				53.248385	100

Peak# 1 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	10.00140347	0.676803096	14.77741979	8.674938642	11.32786829
Rtel	-42.9889177	3.237753966	-13.2773886	-49.3345842	-36.6432511

Peak# 2 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	89.92229099	28.95302318	3.10579971	33.17732777	146.6672542
Rtel	4.439865717	0.759119147	5.848707326	2.952069855	5.92766158

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
61.55931198	11.28301626	0.833547338	54.62063491
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
10.86624249	11.69978983	0.416773765	0.416773573

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	61.55931198	1.858652281	33.12040268	57.91654367	65.20208029
Ctr	11.28301626	0.0121013	932.3804849	11.25929895	11.30673357
Wid1	0.353975327	0.012803321	27.64714924	0.328882128	0.379068526

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
10.06610724	22.98878373	0.129300575	1.385489219
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
22.92413413	23.05343471	0.064649591	0.064650983

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	10.06610724	4.621567163	2.178072262	1.008308441	19.12390604
Ctr	22.98878373	0.029080543	790.5211241	22.93178884	23.04577862
Wid1	0.054910018	0.029170129	1.88240576	-0.00226045	0.112080486

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```
Peak# 5  Gaussian
   PkAmpl        PkCtr         Wid@HM        Area
   55.86706436   32.45665385   0.02827827    1.681823491
   XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
   32.44251459   32.47079286   0.014139256   0.014139014
   Parm  Value       Std Error     t-value       95% Confidence Limits
   Ampl  55.86706436 9797.443081   0.005702209   -19146.119   19257.85312
    Ctr  32.45665385 0.641442609   50.59946657   31.19949196  33.71381573
   Widl  0.012009768 0.896566306   0.013395292   -1.74516846  1.769187998

Peak# 6  Gaussian
   PkAmpl        PkCtr         Wid@HM        Area
   -3.8286907    37.22292215   1.089330592   -4.43956231
   XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
   36.67825711   37.7675877    0.544665043   0.544665549
   Parm  Value       Std Error     t-value       95% Confidence Limits
   Ampl  -3.8286907  1.601915424   -2.39007044   -6.96828103  -0.68910036
    Ctr  37.22292215 0.221998233   167.6721549   36.78782833  37.65801598
   Widl  0.462593901 0.226600052   2.041455401   0.018480982  0.90670682


Total Peaks= 6   Coefficient Count= 16   Fitted Count=16
Std Error for Curve= 6.04841558      r2= 0.6633302438
Source    Sum of Squares    DF       Mean Square        F
Regr      73304.375         15       4886.9583          133.584
Error     37205.248         1017     36.583331
Total     110509.62         1032
```

E6. CORRECTED LITHIUM FLUORIDE DATA TAKEN 22 OCTOBER 1992

1 mm LiF Crystal <220>
22 Oct 1992

1 mm LiF Crystal 22 Sep 92
Gauss1(37.0424, 11.1432, 0.225737)
Gauss2(2.01749, 22.2739, 0.340583)
Gauss3(-12.3287, 42.6176, 0.41531)
Bkgnd(8.36983, -0.238746, 0.0101402) X2=30556.982 r2=0.53891129
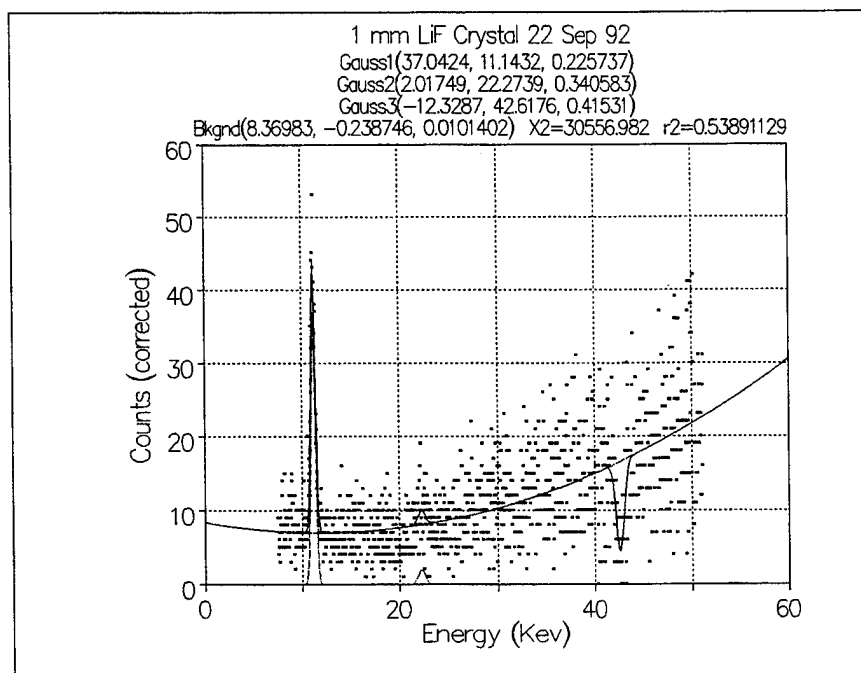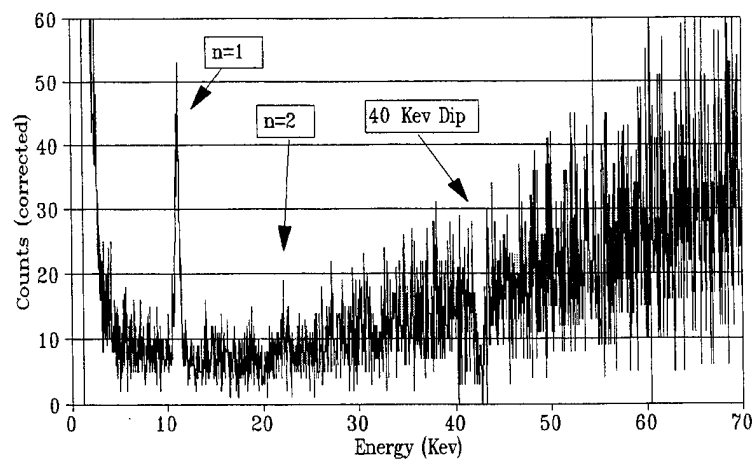
Description: 1 mm LiF Crystal 22 Oct 92
X-Y Table Size: 2020   Active Points: 1206
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: L1022X1.PRN

Curve-Fit Std Error= 5.05886473   r2= 0.538911288

Background Coefficients [y=a+bx+cx^2+dx^3]

Background	a	b	c	d
Order= 2	8.3698256	-0.238746	0.0101402	

Curve-Fit Coefficients

Peak#	Type	Ampl	Ctr	Wid1	Wid2	Wid3
1	Gaussian	37.042364	11.143188	0.2257372		
2	Gaussian	2.0174933	22.273939	0.3405828		
3	Gaussian	-12.32871	42.617646	0.4153104		

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Gaussian	37.042364	11.143188	0.5315696	20.96002	212.83898
2	Gaussian	2.0174933	22.273939	0.8020092	1.722363	17.489773
3	Gaussian	-12.32871	42.617646	0.977982	-12.83455	-130.3288
	Total				9.8478293	100

Peak# 1 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
37.042364	11.14318764	0.531569629	20.96001986
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
10.87740284	11.40897247	0.265784793	0.265784836

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	37.042364	1.878596176	19.71810891	33.36239072	40.72233728
Ctr	11.14318764	0.013116124	849.5793298	11.11749452	11.16888075
Wid1	0.2257372	0.01342549	16.81407592	0.199438071	0.252036329

Peak# 2 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
2.017493298	22.27393941	0.802009231	1.722362997
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
21.87293532	22.67494455	0.40100409	0.401005141

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	2.017493298	1.524711863	1.323196433	-0.96925766	5.004244251
Ctr	22.27393941	0.295798085	75.30116157	21.69450192	22.8533769
Wid1	0.340582756	0.300035509	1.135141493	-0.2471554	0.928320914

Peak# 3 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
-12.3287141	42.61764584	0.977981987	-12.8345535
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
42.12865522	43.10663721	0.488990616	0.48899137

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	-12.3287141	1.383324768	-8.91237861	-15.0385025	-9.61892564
Ctr	42.61764584	0.053462657	797.1479156	42.51291809	42.72237359
Wid1	0.415310364	0.054520574	7.617497977	0.308510266	0.522110462

Background Order=2   Area=509.99836294

Parm	Value	Std Error	t-value	95% Confidence Limits	
a	8.369825611	0.850715621	9.838570494	6.70336275	10.03628847
b	-0.23874592	0.063704623	-3.74770168	-0.36353661	-0.11395523
c	0.010140167	0.001060948	9.557651491	0.008061882	0.012218452

Total Peaks= 3   Coefficient Count= 12   Fitted Count=12
Std Error for Curve= 5.058864727   r2= 0.5389112875

Source	Sum of Squares	DF	Mean Square	F
Regr	35714.391	11	3246.7628	126.866
Error	30556.982	1194	25.592112	
Total	66271.373	1205		

E7. CORRECTED SILICON DATA TAKEN 05 SEPTEMBER 1991

320 um Si Crystal <111>
5 Sep 1991
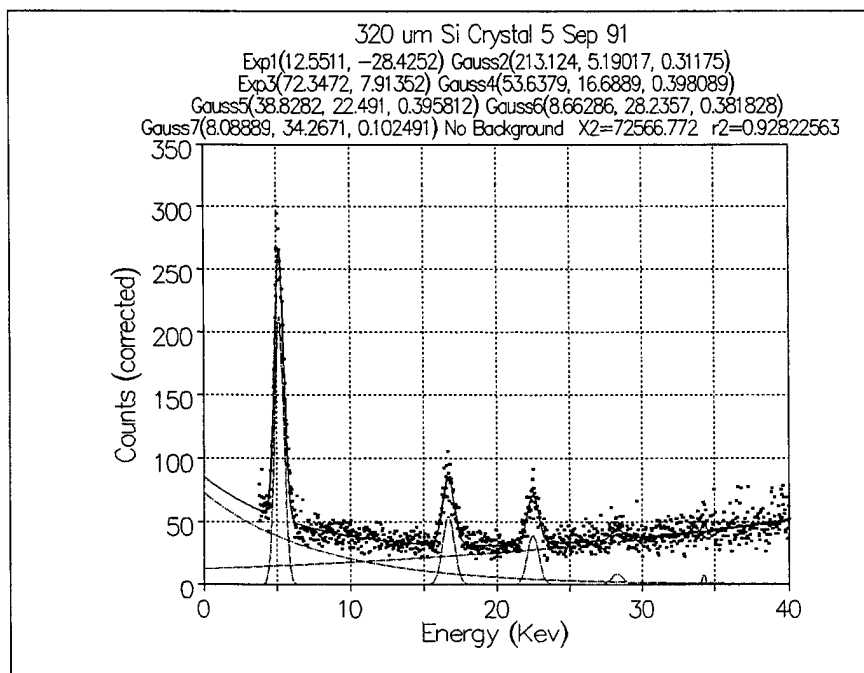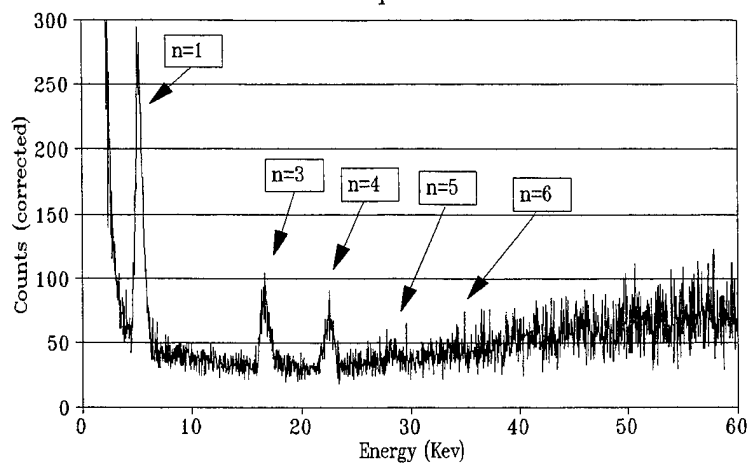
320 um Si Crystal 5 Sep 91
Exp1(12.5511, −28.4252) Gauss2(213.124, 5.19017, 0.31175)
Exp3(72.3472, 7.91352) Gauss4(53.6379, 16.6889, 0.398089)
Gauss5(38.8282, 22.491, 0.395812) Gauss6(8.66286, 28.2357, 0.381828)
Gauss7(8.08889, 34.2671, 0.102491) No Background X2=72566.772 r2=0.92822563

PeakFit Numerical Summary

Description: 320 um Si Crystal 5 Sep 91
X-Y Table Size: 1916   Active Points: 1085
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S905T32.PRN

Curve-Fit Std Error= 8.25069059   r2= 0.928225626

Curve-Fit Coefficients

Peak#	Type	Ampl	Rte1	Amp2	Rte2
1	Exp	12.551064	-28.42516		
2	Gaussian	213.12394	5.1901745	0.3117504	
3	Exp	72.347153	7.9135208		
4	Gaussian	53.637888	16.688854	0.398089	
5	Gaussian	38.828177	22.490957	0.3958121	
6	Gaussian	8.6628599	28.235708	0.3818276	
7	Gaussian	8.088892	34.267095	0.1024914	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Gaussian	213.12394	5.1901745	0.7341157	166.54386	61.92146
3	Exp	0	0	0	0	0
4	Gaussian	53.637888	16.688854	0.9374266	53.523152	19.900053
5	Gaussian	38.828177	22.490957	0.9320641	38.523511	14.323146
6	Gaussian	8.6628599	28.235708	0.8991324	8.2912199	3.082698
7	Gaussian	8.088892	34.267095	0.2413483	2.0781006	0.7726434
	Total				268.95985	100

Peak# 1   Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	12.5510644	1.519242852	8.261394404	9.573941785	15.52818701
Rte1	-28.4251578	2.626347992	-10.8230737	-33.571774	-23.2785415

Peak# 2   Gaussian

PkAmpl	PkCtr	Wid@HM	Area
213.1239437	5.190174534	0.734115726	166.5438641
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.823116693	5.557232419	0.367057841	0.367057886

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	213.1239437	2.596736018	82.07378117	208.0353553	218.212532
Ctr	5.190174534	0.004232279	1226.330947	5.18188092	5.198468147
Wid1	0.311750379	0.00477205	65.32839382	0.302399024	0.321101733

Peak# 3   Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	72.34715305	4.344022989	16.65441302	63.83456466	80.85974144
Rte1	7.913520815	0.826097911	9.579398168	6.294691563	9.532350068

Peak# 4   Gaussian

PkAmpl	PkCtr	Wid@HM	Area
53.63788803	16.68885362	0.937426613	53.52315151
XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
16.22014053	17.15756715	0.468713085	0.468713528

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	53.63788803	2.221073018	24.14953835	49.2854524	57.99032365
Ctr	16.68885362	0.018850869	885.3094927	16.65191328	16.72579396
Wid1	0.398088989	0.019406534	20.51314153	0.360059761	0.436118217

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```
Peak# 5  Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  38.82817702     22.49095715     0.932064123     38.52351103
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  22.02492424     22.95698837     0.466032906     0.466031217
  Parm  Value          Std Error       t-value         95% Confidence Limits
  Ampl  38.82817702    2.230418535     17.40847128     34.45742783     43.1989262
  Ctr   22.49095715    0.025959774     866.3772167     22.44008613     22.54182817
  Wid1  0.395812091    0.026831001     14.75204359     0.34323381      0.448390373

Peak# 6  Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  8.662859917     28.23570809     0.899132382     8.291219864
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  27.78614226     28.68527464     0.44956583      0.449566552
  Parm  Value          Std Error       t-value         95% Confidence Limits
  Ampl  8.662859917    2.271326081     3.814009794     4.211947921     13.11377191
  Ctr   28.23570809    0.114272564     247.0908764     28.0117785      28.45963768
  Wid1  0.381827602    0.118170368     3.231162005     0.150259836     0.613395368

Peak# 7  Gaussian
  PkAmpl          PkCtr           Wid@HM          Area
  8.088892034     34.26709478     0.241348268     2.078100552
  XL @HM          XR @HM          Ctr-XL@HM       Ctr-XR@HM
  34.14642035     34.38776861     0.120674433     0.120673835
  Parm  Value          Std Error       t-value         95% Confidence Limits
  Ampl  8.088892034    4.343694373     1.86221482      -0.4230524      16.60083647
  Ctr   34.26709478    0.063396517     540.5201457     34.14286237     34.39132719
  Wid1  0.102491436    0.063862772     1.604869835     -0.02265465     0.227637526

Total Peaks= 7   Coefficient Count= 19   Fitted Count=19
Std Error for Curve= 8.250690594      r2= 0.9282256264
Source    Sum of Squares    DF      Mean Square         F
Regr      938473.36         18      52137.409           765.894
Error     72566.772         1066    68.073895
Total     1011040.1         1084
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E8. CORRECTED SILICON DATA TAKEN 05 SEPTEMBER 1991
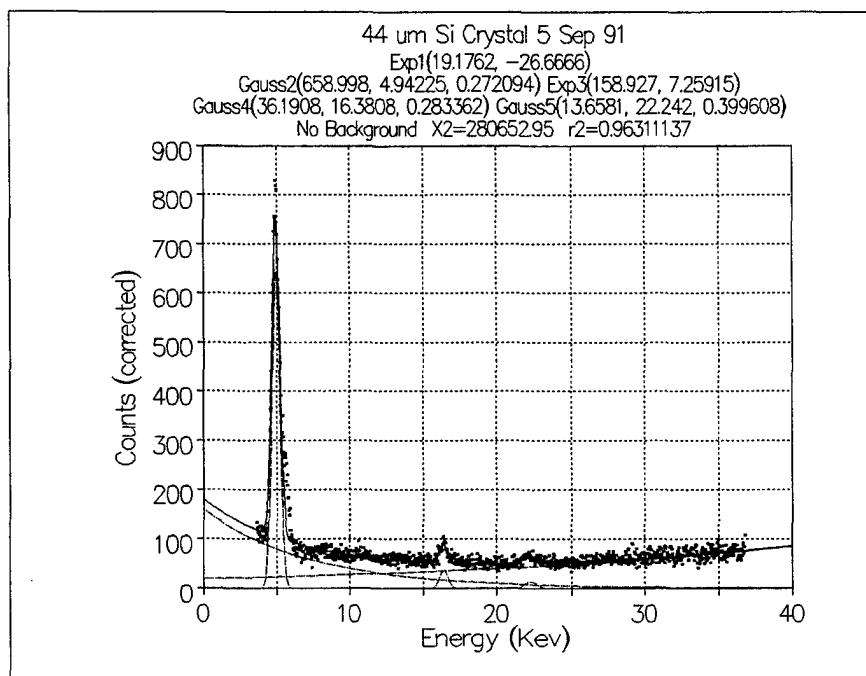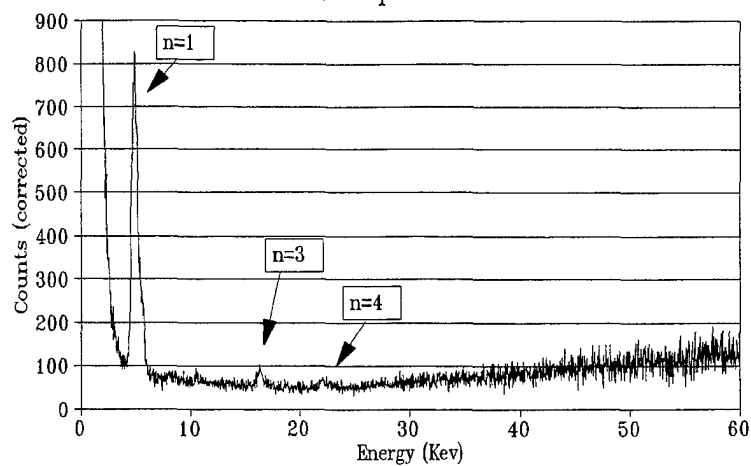
44 um Si Crystal <111>
5 Sep 1991

44 um Si Crystal 5 Sep 91
Exp1(19.1762, −26.6666)
Gauss2(658.998, 4.94225, 0.272094) Exp3(158.927, 7.25915)
Gauss4(36.1908, 16.3808, 0.283362) Gauss5(13.6581, 22.242, 0.399608)
No Background   X2=280652.95   r2=0.96311137

PeakFit Numerical Summary

Description: 44 um Si Crystal 5 Sep 91
X-Y Table Size: 1916   Active Points: 993
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S905T44.PRN

Curve-Fit Std Error= 16.9227822   r2= 0.963111367

Curve-Fit Coefficients

Peak#	Type	Ampl	Rte1	Amp2	Rte2
1	Exp	19.176236	-26.66662		
2	Gaussian	658.99824	4.9422514	0.2720942	
3	Exp	158.92712	7.2591474		
4	Gaussian	36.190783	16.380823	0.283362	
5	Gaussian	13.658097	22.242023	0.3996076	

Measured Values

Peak#	Type	PkAmpl	PkCtr	Wid@HM	Area	%Area
1	Exp	0	0	0	0	0
2	Gaussian	658.99824	4.9422514	0.6407329	449.46398	91.943016
3	Exp	0	0	0	0	0
4	Gaussian	36.190783	16.380823	0.667265	25.705739	5.258404
5	Gaussian	13.658097	22.242023	0.9410016	13.680875	2.7985801
	Total				488.8506	100

Peak# 1 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	19.17623649	3.221667458	5.952270601	12.86137518	25.49109781
Rte1	-26.6666154	3.507501612	-7.60273788	-33.5417465	-19.7914842

Peak# 2 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
658.9982391	4.942251359	0.640732865	449.4639844

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
4.621884914	5.262617779	0.320366445	0.32036642

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	658.9982391	5.669149315	116.2428792	647.8860147	670.1104635
Ctr	4.942251359	0.002617762	1887.967908	4.937120225	4.947382493
Wid1	0.272094245	0.002910913	93.47383532	0.2663885	0.277799991

Peak# 3 Exp

PkAmpl	PkCtr	Wid@HM	Area
0	0	0	0

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
0	0	0	0

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	158.927118	9.30384888	17.08186795	140.690439	177.1637971
Rte1	7.259147447	0.729310663	9.953436606	5.82960956	8.688685334

Peak# 4 Gaussian

PkAmpl	PkCtr	Wid@HM	Area
36.19078254	16.38082348	0.667264951	25.70573938

XL @HM	XR @HM	Ctr-XL@HM	Ctr-XR@HM
16.04719086	16.71445581	0.333632622	0.33363233

Parm	Value	Std Error	t-value	95% Confidence Limits	
Ampl	36.19078254	5.382078198	6.72431377	25.64125257	46.74031251
Ctr	16.38082348	0.048333088	338.9153091	16.28608473	16.47556223
Wid1	0.283362	0.049316049	5.745837459	0.186696527	0.380027473

```
Peak# 5  Gaussian
  PkAmpl         PkCtr         Wid@HM         Area
  13.65809679    22.24202326   0.941001625    13.68087541
  XL @HM         XR @HM        Ctr-XL@HM      Ctr-XR@HM
  21.77152236    22.71252399   0.470500894    0.470500731
 Parm  Value          Std Error     t-value       95% Confidence Limits
 Ampl  13.65809679    4.554691273   2.998687721   4.730346148   22.58584744
  Ctr  22.24202326    0.152088846   146.2436194   21.94391056   22.54013595
 Widl  0.399607571    0.157334203   2.539864583   0.091213335   0.708001807

Total Peaks= 5   Coefficient Count= 13   Fitted Count=13
Std Error for Curve= 16.9227822      r2= 0.9631113669
Source    Sum of Squares    DF       Mean Square        F
Regr      7327461.6         12       610621.8           2132.2
Error     280652.95         980      286.38056
Total     7608114.5         992
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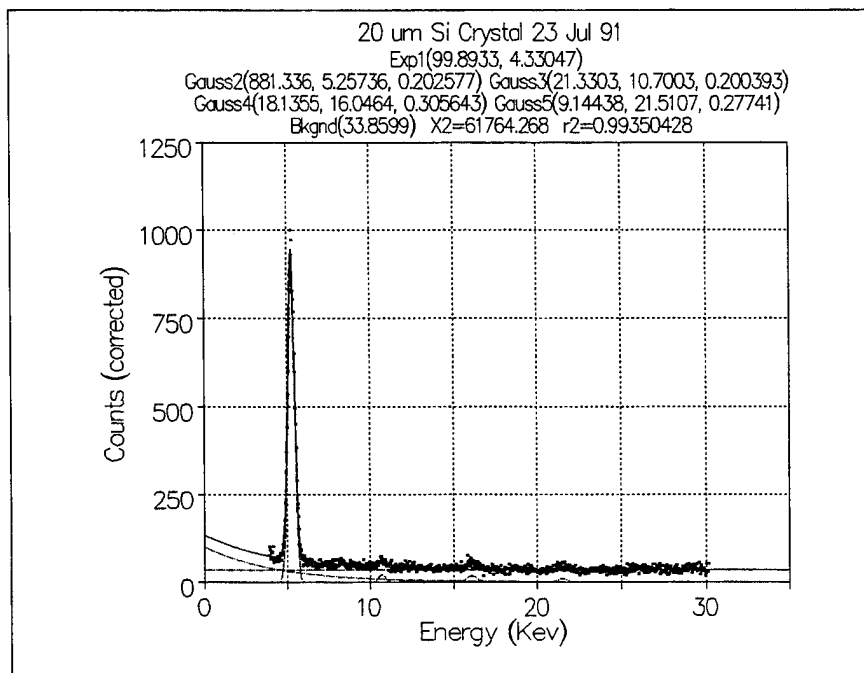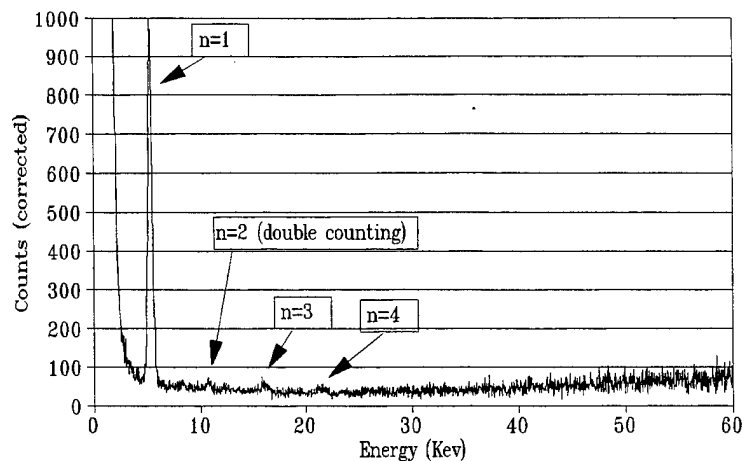
20 um Si Crystal <111>
23 Jul 1991

20 um Si Crystal 23 Jul 91
Exp1(99.8933, 4.33047)
Gauss2(881.336, 5.25736, 0.202577) Gauss3(21.3303, 10.7003, 0.200393)
Gauss4(18.1355, 16.0464, 0.305643) Gauss5(9.14438, 21.5107, 0.27741)
Bkgnd(33.8599) X2=61764.268 r2=0.99350428

PeakFit Numerical Summary

Description: 20 um Si Crystal 23 Jul 91
X-Y Table Size: 1952   Active Points: 846
X Variable: Energy (Kev)
Y Variable: Counts (corrected)
File Source: S723T20.PRN

Curve-Fit Std Error= 8.62120827   r2= 0.99350428

Background Coefficients [y=a+bx+cx^2+dx^3]
Background   a   b   c   d
    Order= 0   33.859902

Curve-Fit Coefficients
Peak# Type   Ampl   Rte1   Amp2   Rte2
  1 Exp   99.893337 4.330475
  2 Gaussian 881.33565 5.2573613 0.202577
  3 Gaussian 21.330343 10.700282 0.2003925
  4 Gaussian 18.135484 16.046351 0.3056427
  5 Gaussian 9.1443786 21.510675 0.2774097

Measured Values
Peak# Type   PkAmpl   PkCtr   Wid@HM   Area   %Area
  1 Exp   0   0   0   0   0
  2 Gaussian 881.33565 5.2573613 0.4770317 447.53122 93.528238
  3 Gaussian 21.330343 10.700282 0.4718878 10.714436 2.2391786
  4 Gaussian 18.135484 16.046351 0.7197326 13.894189 2.9037059
  5 Gaussian 9.1443786 21.510675 0.6532486 6.3586593 1.3288776
     Total   478.4985   100

Peak# 1 Exp
  PkAmpl   PkCtr   Wid@HM   Area
  0   0   0   0
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  0   0   0   0
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 99.89333723   9.512101224   10.50171091   81.23915734   118.5475171
  Rte1 4.330474988   0.321031873   13.48923691   3.700899443   4.960050532

Peak# 2 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  881.3356451   5.257361253   0.47703171   447.5312174
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  5.018845524   5.495877234   0.238515729   0.238515981
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 881.3356451   3.176387788   277.4647505   875.1064316   887.5648586
  Ctr   5.257361253   0.000827453   6353.664473   5.255738534   5.258983971
  Wid1 0.202576961   0.000881756   229.7426652   0.200847749   0.204306172

Peak# 3 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  21.33034285   10.70028179   0.471887795   10.71443602
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  10.46433789   10.93622568   0.2359439   0.235943895
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 21.33034285   3.148916022   6.773868437   15.15500424   27.50568146
  Ctr   10.70028179   0.033874099   315.8838799   10.6338513   10.76671228
  Wid1 0.200392541   0.034721221   5.771471546   0.132300761   0.268484322

Peak# 4 Gaussian
  PkAmpl   PkCtr   Wid@HM   Area
  18.13548436   16.04635095   0.719732616   13.89418909
  XL @HM   XR @HM   Ctr-XL@HM   Ctr-XR@HM
  15.68648514   16.40621776   0.359865806   0.359866811
  Parm Value   Std Error   t-value   95% Confidence Limits
  Ampl 18.13548436   2.542285696   7.133535143   13.14980836   23.12116035
  Ctr   16.04635095   0.049209914   326.0796398   15.94984539   16.1428565
  Wid1 0.305642729   0.050017387   6.110729603   0.20755364   0.403731817

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```
Peak# 5  Gaussian
  PkAmpl        PkCtr         Wid@HM        Area
  9.144378603  21.51067526   0.653248611   6.358659321
  XL @HM        XR @HM        Ctr-XL@HM     Ctr-XR@HM
  21.18405111  21.83729972   0.326624155   0.326624456
  Parm  Value         Std Error     t-value        95% Confidence Limits
  Ampl  9.144378603   2.669719848   3.425220294    3.908791518   14.37996569
   Ctr  21.51067526   0.092963417   231.3886035    21.32836472   21.6929858
  Wid1  0.277409672   0.09462303    2.931735238    0.091844465   0.462974878

Background  Order=0    Area=888.64821091
  Parm   Value         Std Error     t-value        95% Confidence Limits
   a     33.85990172   0.523527445   64.67645979    32.83321215   34.88659129

Total Peaks= 5   Coefficient Count= 15   Fitted Count=15
Std Error for Curve= 8.621208271      r2= 0.99350428
Source   Sum of Squares    DF       Mean Square          F
Regr     9446691.8         14       674763.7             9078.53
Error    61764.268         831      74.325232
Total    9508456           845
```

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    Walnut Creek, CA 94596

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